DOCUMENT RESUME

ED 334 447 CE 058 529

AUTHOR	Peterson, Dennis R.; Rehberger, Thomas
TITLE	Biotechnology in Agriculture. Teacher Edition.
INSTITUTION	Mid-America Vocational Curriculum Consortium, Stillwater, Okla.
PUB DATE	91
NOTE	318p.
AVAILABLE FROM	Mid-America Vocational Curriculum Consortium, 1500 West Seventh Avenue, Stillwater, OK 74074 (order no. 302201: $24.00).
PUB TYPE	Guides - Classroom Use - Teaching Guides (For Teacher) (052)
EDRS PRICE	MF01 Plus Postage. PC Not Available from EDRS.
DESCRIPTORS	*Agricultural Education; Agricultural Engineering; Agricultural Production; *Animal Husbandry; Biology; *Botany; Classroom Techniques; Course Content; Educational Resources; Field Crops; *Genetic Engineering; Learning Activities; Learning Modules; Lesson Plans; Postsecondary Education; Secondary Education; Teaching Methods; *Technological Advancement; Units of Study; Zoology
IDENTIFIERS	*Biotechnology

ABSTRACT

This curriculum guide is designed to help teachers to present a course that emphasizes the interrelationship of science and technology and the impact of this technology on agriculture and agricultural products. The guide contains six units that each contain some or all of the following basic components of a unit of instruction: objective sheet, suggested activities for the teacher, answers to assignment sheets, written test and answers, unit evaluation form, teacher supplements, transparency masters, information sheets, assignment sheets, student supplements, job sheets, and laboratory sheets. The units cover the following topics: (1) introduction to biotechnology; (2) genetics and genetic engineering; (3) impacts of biotechnology; (4) biotechnology in plant science; (5) biotechnology in animal science; and (6) microbial biotechnology in agriculture. Supplemental materials include information on use of the publication; a student competency profile sheet; an instructional/task analysis; a list of related and academic workplace skills; a tools, equipment, and materials list; 31 references; and a 124-term glossary. (KC)

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Biotechnology in Agriculture

Teacher Edition

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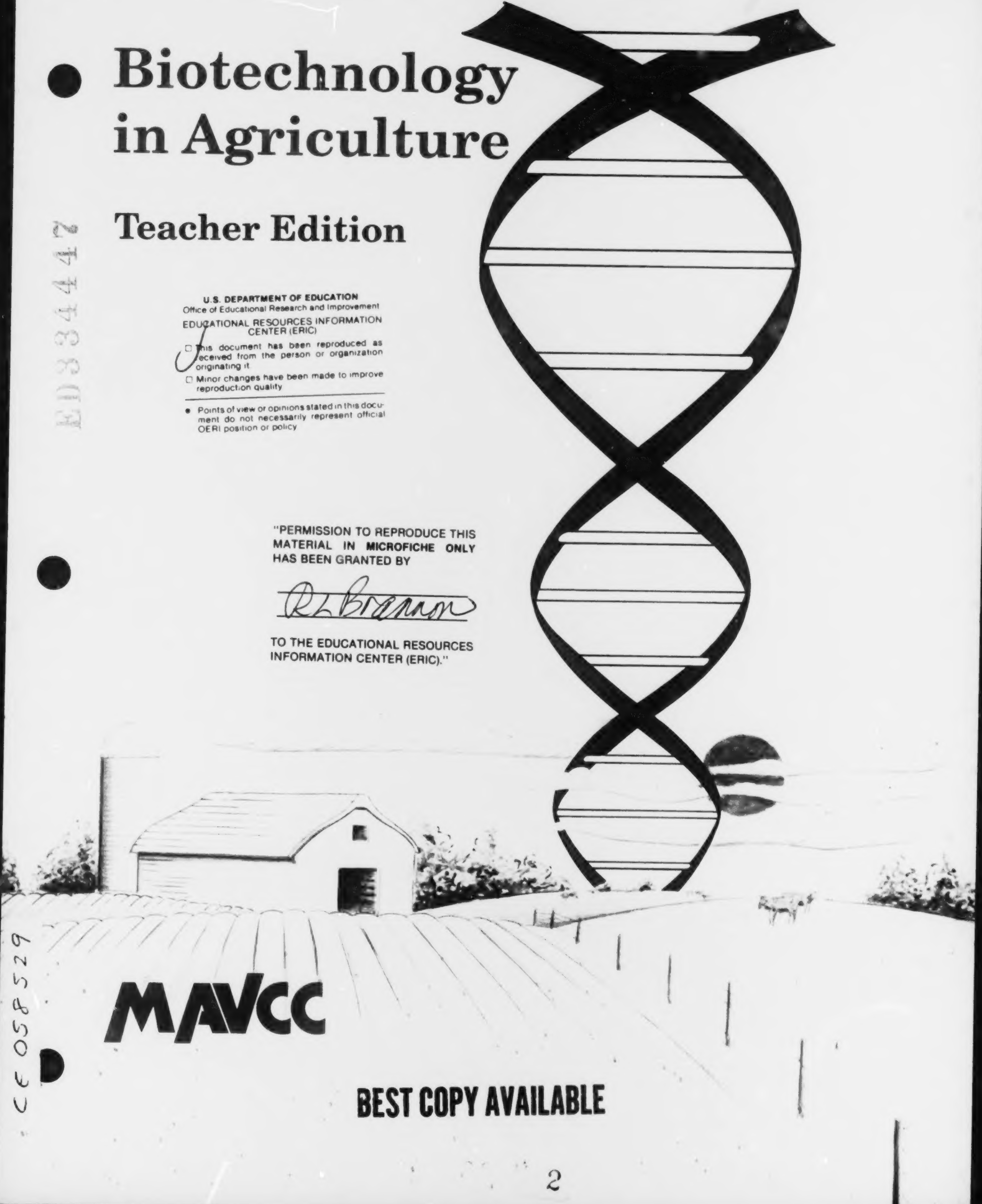

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Biotechnology in Agriculture

Written by

Dennis R. Peterson
Agriculture Technology Instructor
Devils Lake Area Vo-Tech Center
Devils Lake, North Dakota

and

Dr. Thomas Rehberger
Assistant Professor of Food Microbiology
Oklahoma State University
Stillwater, Oklahoma

Project Coordinated by

Mary Kellum
MAVCC Curriculum Specialist

Developed by

The Mid-America Vocational Curriculum Consortium, Inc.

Board of Directors

Sylvia Clark, Texas, Chairman
Larry Nelson, South Dakota, Vice-Chairman
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Jean McEntire, Arkansas
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Harley Schlichting, Missouri
Ann Masters, Nebraska
Ann Benson, Oklahoma

Jim Steward, Executive Director

91-008295

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Printed in the United States of America by the
Oklahoma Department of Vocational-Technical Education
Stillwater, OK 74074-4364

Mid-America Vocational Curriculum Consortium, Inc.
1500 West Seventh Avenue
Stillwater, OK 74074-4364

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Biotechnology in Agriculture

Teacher Edition

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Foreword

Biotechnology in Agriculture is designed to emphasize the interrelationship of science and technology and the impact of this technology on agriculture and agricultural products. Career opportunities await those students who enjoy experimentation and application of scientific principles to the world of agriculture.

The success of these instructional materials is due to the capabilities of the personnel who worked with its development. Appreciation is extended to them for their valuable contributions.

These instructional materials are not only designed for student use, but also to assist teachers in improving instruction. Every effort has been made to make these materials basic, readable, and by all means usable. Teachers will need to develop instructional strategies for localizing, individualizing, supplementing, and motivating these instructional materials.

Special attention should be given to the teacher suggestions in each unit of instruction on ways to increase reinforcement of the academic and workplace basic skills. By reinforcing these basic skills, the teacher should assist students in improving their employability skills.

As you use these instructional materials, we hope you will find they contribute to the quality of your program. If any problems occur or if you have suggestions for improvement of these materials, please call or write us.

Sylvia Clark, Chairman
Board of Directors
Mid-America Vocational
Curriculum Consortium

Jim Steward
Executive Director
Mid-America Vocational
Curriculum Consortium

Acknowledgements

Appreciation is extended to those individuals who contributed their time and talent to the development of *Biotechnology in Agriculture*.

The contents of this publication were planned and reviewed by the following members of the Mid-America Vocational Curriculum Consortium biotechnology committee:

Bob Bell
Assistant Agriculture Education Supervisor
Brookings, South Dakota

Pat Brock
Mathematical and Science Education Center
St. Louis, Missouri

Edward Funkhouser
Texas A&M University
College Station, Texas

Travis Hooper
Area Supervisor of Agriculture
Little Rock, Arkansas

Jane Huston
Assistant Director of MAVCC
Stillwater, Oklahoma

Phillip McClean
North Dakota State University
Fargo, North Dakota

Mary Musgrave
Louisiana State University
Baton Rouge, Louisiana

Dennis Peterson
Devils Lake Area Vo-Tech Center
Devils Lake, North Dakota

Thomas Rehberger
Oklahoma State University
Stillwater, Oklahoma

Edward Smith
State Supervisor of Agriculture Education
Stillwater, Oklahoma

Lori VanBoening
Central Community College
Hastings, Nebraska

Mike Womochil
Agriculture Instructor
Concordia, Kansas

Steve Woskow
Great Lakes Biochemical Company
Milwaukee, Wisconsin

We wish to thank this committee for their input and assistance in developing this publication.

We also want to thank the following groups for providing valuable artwork and information used in this work.

- Council for Agricultural Science and Technology, Ames, Iowa
- Industrial Biotechnology Association, Washington, D.C.
- Monsanto Company, St. Louis, Missouri
- National Association of Animal Breeders, Columbia, Missouri
- National Academy Press, Washington, D.C.

- Pioneer Hi-Bred International, Inc., Johnston, Iowa
- University of Wisconsin-Madison, Bottle Biology Program, Madison, Wisconsin

Special appreciation is extended to the employees of the Graphics Division of the Oklahoma Department of Vocational and Technical Education for the artwork, phototypesetting, and printing of this test.

Thanks are also extended to Mary Kellum, MAVCC Curriculum Specialist, for her assistance with the editing of this book, as well as the coordination of the project.

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Use of Introductory Materials

Introductory materials are included in the teacher guide only and contain useful information to assist administrators and teachers in planning for instruction.

In addition to the general information such as the table of contents, foreword, and acknowledgements page, information is included on the following:

1. **Use of this publication**—Explains the components of a unit of instruction and how they should be used as part of the teaching/ learning process.

2. **Competency profile**—Provides a record of student performance for each task included in a unit of instruction. This becomes a part of the student's permanent records and should be utilized when directing the student toward employment opportunities.

3. **Instructional/task analysis**—Provides a quick review of contents of the publication; identifies cognitive (knowledge) skills and psychomotor (doing) skills addressed in each unit of instruction.

4. **Related academic and workplace skills list**—Classifies unit tasks (assignment sheets, job sheets, and laboratory sheets) according to related academic and workplace skills being reinforced. Skill areas reflected by skill groups, sub skills, and descriptions have been identified using *Workplace Basics: The Skills Employers Want*, developed by the American Society for Training and Development (ASTD) and the U.S. Department of Labor and adapted by MAVCC.

5. **Tools, equipment, and materials list**—Provides a comprehensive list of those items needed to successfully complete the assignment sheets, job sheets, and laboratory sheets; assists administrator/teacher in determining program costs.

6. **Reference list**—Provides a comprehensive list of resources used in the development of this publication.

7. **Glossary**—Provides a comprehensive list of terms and definitions presented in the first objective of each unit.

As you use these materials, it is hoped that they will provide useful information to meet a variety of needs.

Use of This Publication

Instructional units

Biotechnology in Agriculture contains six units of instruction. Each instructional unit in a teacher guide includes some or all of the following basic components of a unit of instruction: objective sheet, suggested activities for the teacher, answers to assignment sheets, answers to written test, written test, unit evaluation form, teacher supplements, transparency masters, information sheet, assignment sheets, student supplements, job sheets, and laboratory sheets.

All of the unit components focus on measurable and observable learning outcomes. Teachers are encouraged to supplement, personalize, localize, and motivate with these materials in order to develop a complete teaching/learning process.

Units of instruction are designed for use in more than one lesson or class period of instruction. Careful study of each unit of instruction by the teacher will help to determine the following:

- Amount of materials that can be covered in each class period.
- Skills that must be demonstrated.
- Amount of class time needed for demonstrations.
- Amount of time needed for student practice.
- Supplementary materials, including print and nonprint media and equipment and supplies, that must be ordered.
- Resource people who must be contacted.

Objective sheet (Color code: White)

Each unit of instruction is based on performance objectives which state the goals for successful completion of the course. These performance objectives are stated in two forms: unit objectives which state the expected performance of each student after completion of the unit of instruction, and specific objectives which state what the student must do to reach the unit objective.

The objectives should be provided for students and stressed throughout the teaching/learning process. This will help answer any questions concerning performance requirements for each instructional unit. The objectives can also help determine teaching strategies and instructional methods. Teachers should prepare for each unit by deciding how each objective can best be taught.

Teachers should feel free to modify, delete, or add objectives in order to meet the needs of the students and community. When objectives are added, the teacher should remember to supply the needed information, assignment and/or job sheets, and criterion test items.

Suggested activities (Color code: Pink)

This component is included only in the teacher guide. The suggested activities assist teachers during the preparation stage of the teaching/learning process by providing an instructional plan, teaching suggestions, and a list of supplemental resources. Ways to integrate academic and workplace skills have been included in the teacher suggestions, and skill areas have been noted in bold. (A table of academic and workplace skills with accompanying definitions has been provided on page xxi.) The teacher should read the suggested activities before teaching the units and decide how each objective can best be taught. Time should also be allowed to obtain supplemental materials, prepare audiovisual materials, and contact outside resources. Duties of the teacher will vary according to the particular unit.

References used in the development of each unit are listed in the suggested-activities section, along with suggested supplemental resources that may be used to teach the unit. These materials can be used by the teacher to supplement her or his knowledge of the subject area or to help students with particular interests or objectives in the area covered.

Instructions for evaluating student performance on the job sheets are also included in the suggested-activities section. Teachers should select and discuss with students the rating scale that will be used.

Answers to assignments and written test (Color code: Pink)

Assignment sheet answers and written test answers are designed to assist the teacher in evaluation of student performances.

Written test (Color code: Yellow)

This component provides criterion-referenced evaluation of every cognitive objective listed in the unit of instruction. The test appears in the teacher guide only, but duplication is permitted for student use. If objectives have been added, deleted, or modified, appropriate changes should be made on the written test. It is recommended that the tests be divided into shorter tests covering three or four objectives at a time and given soon after those objectives have been covered. A selection of test items from the units covered may be used for final tests at the end of each term if desired.

Unit evaluation form (Color code: White)

This sheet provides teachers with a record of each students performance on a unit of instruction. It includes space for assignment sheet ratings, job sheet ratings, laboratory sheet ratings, written test scores, and teacher comments. The unit evaluation form is included in the teacher guide only, but may be duplicated.

Use of This Publication

Teacher supplements (Color code: White)

This component is included only in the teacher guide. Teacher supplements are optional materials for the teacher to use. They have three purposes: to provide the teacher with higher level materials to stretch the advanced student, with remedial information or practice to assist the less-advanced student, and with state-of-the-art information in which the teacher may not have background or with information that is not readily available in other books. Some teacher supplements may be duplicated for student use and are marked accordingly.

Transparency masters (Color code: White)

Transparencies are included in the teacher guide only and are used to direct the students' attention to the topic of discussion. They may provide illustrations, charts, schematics, or additional information needed to clarify and reinforce objectives included in the unit of instruction.

Information sheet (Color code: Green)

The information sheet provides the content essential for meeting the cognitive (knowledge) objectives of the unit. Teachers will find that the information sheet serves as an excellent guide for presenting background knowledge necessary to develop the skills specified in the unit objective. Students should read the information sheet before the information is discussed in class. Space is provided in margins for students and teachers to add notes that supplement, localize, personalize, or provide information for the teaching of each objective.

Student supplements (Color code: White)

Student supplements are included in the student manual. The information presented in a student supplement may consist of tables, charts, written information, forms, or other information students will need in order to complete one or more of the assignment and/or job sheets. Students are not directly tested over the information presented in a supplement; however, their ability to apply this information may be evaluated in the completion of assignment sheets or job sheets.

Assignment sheets (Color code: Tan)

Assignment sheets provide students with pencil and paper activities that give students the opportunity to make practical application of the knowledge in the information sheet. Criteria are provided to objectively evaluate student performance.

Job sheets and laboratory sheets (Color code: Blue)

The job sheets and laboratory sheets provide criteria to objectively evaluate student performance, a list of required equipment and materials, and a step-by-step procedure for performing a psychomotor skill or for completing an experiment. The teacher should discuss the equipment and materials available in the classroom and/or laboratory and demonstrate the procedure prior to having students practice procedure. When a student is ready to be evaluated, the teacher should follow instructions for evaluating student performance which may be found in the teacher guide.

Disseminating material

Material may be given out a unit or page at a time to keep the material before the student always new. Some teachers ask students to furnish a three-ring binder or folder for the current unit of study. This is convenient for students taking the material home to study. Upon completion, each unit is then placed in a larger binder. Some teachers prefer to store the material by unit in filing cabinets or boxes until needed.

For best results, provide student materials for each student. Student manuals contain objective sheets, information sheets, student supplements, assignment sheets, job sheets, and laboratory sheets. Students should be allowed to take their materials home at the end of the course.

Biotechnology in Agriculture

Competency Profile

Name: ______________________________

Directions: Evaluate the student using the rating scale below. Write the appropriate number to indicate the degree of competency achieved. The descriptions associated with each of the numbers indicate a level of student performance for each of the tasks listed. The written test scoreline is provided for optional teacher use. It may not be applicable in all cases.

Option A

Rating scale:
4 - Skilled - Can perform job with no additional training.
3 - Moderately Skilled - Has performed job during training program; limited additional training may be required.
2 - Limited Skill - Has performed job during training program; additional training is required to develop skill.
1 - Unskilled - Is familiar with process, but is unable to perform job.
0 - No Exposure - No information or practice provided during training program; complete training required.
NA - Non-applicable.

Option B

Yes - Can perform with no additional training
No - Is unable to perform satisfactorily

______ Unit 1: Introduction to Biotechnology

______1. Evaluate a biotechnology news article.
______2. Record information in a laboratory notebook.
______3. Write a laboratory report.
______4. Determine the effect of hand washing on microorganisms.
______5. ______________________________

______Written Test Score

______ Unit 2: Genetics and Genetic Engineering

______1. Make a model of a DNA molecule.
______2. Genetically engineer a model DNA molecule.
______3. Extract DNA from cells.
______4. Transform bacterial cells.
______5. ______________________________

______Written Test Score

______ Unit 3: Impacts of Biotechnology

______1. Respond to concerns about biotechnology.
______2. Conduct an opinion poll about biotechnology.
______3. Write a position paper on the ethics of biotechnology.
______4. Evaluate salt concentration as an environmental factor affecting plant growth.
______5. ______________________________

______Written Test Score

______ Unit 4: Biotechnology in Plant Science

______1. Design a plant culture facility for commercial use.
______2. Construct a still air chamber from a cardboard box.
______3. Build a light stand for plant culture.
______4. Demonstrate cytoplasmic inheritance of leaf variegation.
______5. Demonstrate micropropagation of dry bean shoot tips.
______6. Demonstrate tissue culture of cauliflower.
______7. ______________________________

______Written Test Score

______ Unit 5: Biotechnology in Animal Science

______1. Write opinion statements about concerns in animal biotechnology.
______2. Observe antigen-antibody reactions.
______3. Evaluate semen.
______4. ______________________________

______Written Test Score

______ Unit 6: Microbial Biotechnology in Agriculture

______1. Identify foods produced by fermentation.
______2. Observe the role of microorganisms in biodegradation.
______3. Demonstrate bacterial nitrogen fixation with inoculated clover seeds.
______4. ______________________________

______Written Test Score

COMMENTS: ____

____

____

____

____

Evaluator: __________________________ Date:________________

*** Permission to duplicate this profile is granted.**

Instructional/Task Analysis

Related Information: What the Student Should Know

Application: What the Student Should Be Able to Do

Unit 1: Introduction to Biotechnology

1. Terms and definitions
2. Definition of biotechnology
3. Historical events in biotechnology
4. Steps in the scientific method
5. Guidelines for maintaining a laboratory notebook
6. Purposes of maintaining a laboratory notebook
7. Parts of a laboratory report
8. Laboratory safety rules
9. Aseptic technique
10. Evaluate a biotechnology news article
11. Record information in a laboratory notebook
12. Write a laboratory report
13. Determine the effect of hand washing on microorganisms

Unit 2: Genetics and Genetic Engineering

1. Terms and definitions
2. Organization of living material
3. Basic cell structures
4. Types of cell reproduction
5. Structures of genetic material
6. Basic stages involved in the transfer of genetic information
7. Genetic engineering
8. Steps in the process of genetic engineering

Related Information: What the Student Should Know

9. Vector systems for gene transfer
10. Other methods of gene transfer
11. Process of sorting DNA by gel electrophoresis

Application: What the Student Should Be Able to Do

12. Make a model of a DNA molecule
13. Genetically engineer a model DNA molecule
14. Extract DNA from cells
15. Transform bacterial cells

Unit 3: Impacts of Biotechnology

1. Terms and definitions
2. Benefits of biotechnology
3. Concerns about biotechnology
4. Environmental impacts of biotechnology
5. Regulatory agencies and laws controlling biotechnology
6. Ethical issues impacting biotechnology
7. Types of companies in the biotechnology industry
8. Work areas in agricultural biotechnology
9. Positions, salary ranges, and educational requirements for careers in biotechnology

10. Respond to concerns about biotechnology
11. Conduct an opinion poll about biotechnology
12. Write a position paper on the ethics of biotechnology
13. Evaluate salt concentration as an environmental factor affecting plant growth

Unit 4: Biotechnology in Plant Science

1. Terms and definitions
2. Purposes of plant biotechnology
3. Differences between traditional plant breeding and genetic engineering of plants
4. Requirements for laboratory plant culture

Unit 5: Biotechnology in Animal Science

20 ml normal saline solution
30 ml test tubes, 4
Antigen-Antibody reaction kit (Modern Biology Kit #2-8 recommended)
Beaker
Bricks, 2
Eye droppers, 2
Fresh or frozen (or both) bull semen sample
Glass thermometer for water bath
Graduated cylinder
Gram scale or balance
Immersion oil for microscope
Microscope with 10X, 40X, and 100X (oil immersion) objectives
Microscope slides and cover slips
Plate glass about 12″ × 12″
Semen stain
Spatulas
Test tube forceps
Test tubes
Trouble light with 75 watt bulb
Water bath at 37°C
Water bath for boiling water or hot plate
Wide mouth pint jar

Unit 6: Microbial Biotechnology in Agriculture

Bunsen burner and rubber tubing for connection
Clear packing tape
Compost bacteria starter culture
Food scraps
Leaves and other plant material
Marking pen
Nylon stocking
Pyrex test tube
Razor blade or knife
Rubber bands, 4
Scissors
Seed inoculum kit (Carolina Biological Kit #15-4720 recommended)
Soil
Thermometers, 4
Two-liter soda bottles, 12 total
Water

Related Information: What the Student Should Know

5. Micropropagation and tissue culture
6. Agricultural applications of plant culture
7. Impacts of laboratory research on production agriculture

Application: What the Student Should Be Able to Do

8. Design a plant culture facility for commercial use
9. Construct a still air chamber from a cardboard box
10. Build a light stand for plant culture
11. Demonstrate cytoplasmic inheritance of leaf variegation
12. Demonstrate micropropagation of dry bean shoot tips
13. Demonstrate tissue culture of cauliflower

Unit 5: Biotechnology in Animal Science

1. Terms and definitions
2. Purposes of biotechnology in animal science
3. Differences between traditional animal breeding and genetic engineering of animals
4. Ways to use biotechnology for making changes in animals and animal products
5. Terminology related to immunology
6. Methods of stimulating an immune response
7. Types of immunity
8. Monoclonal antibodies
9. Uses for monoclonal antibodies
10. Technologies in animal biotechnology
11. Production applications of animal biotechnology
12. Write opinion statements about concerns in animal biotechnology
13. Observe antigen-antibody reactions
14. Evaluate semen

Related Information: What the Student Should Know

Application: What the Student Should Be Able to Do

Unit 6: Microbial Biotechnology in Agriculture

1. Terms and definitions
2. Types of microorganisms used in biotechnology
3. Purposes of fermentation
4. Components of a fermentation system
5. Types of fermentation systems
6. Steps in the fermentation process
7. Products of fermentation
8. How microbial biotechnology can benefit production agriculture
9. Benefits of microbial biotechnology to the food processing industry
10. Benefits of microbial biotechnology to the environment
11. Regulatory status of microbial biotechnology

12. Identify foods produced by fermentation
13. Observe the role of microorganisms in biodegradation
14. Demonstrate bacterial nitrogen fixation with inoculated clover seeds

Academic and Workplace Skills
(Classifications and Definitions)

Skill Groups	Sub Skills	Definitions
Learning Skills	Learning to learn	Developing ability to apply knowledge to other situations; knowing how to learn.
Foundation Skills	Reading	Comprehending written information and analyzing, summarizing, and applying what has been read to a specific task.
	Writing	Communicating a thought, idea or fact in written form in a clear, concise manner.
	Math	Applying computation skills such as reasoning, estimation, and problem solving as they are actually used on the job.
	Science	Applying knowledge learned through study or practice that is based on scientific principles as they relate to specific tasks.
Communication Skills	Listening	Listening for content, conversation, long-term contexts, emotional meaning, and directions.
	Oral communication	Communicating a thought, idea, or fact in spoken form in a clear, concise manner.
Adaptability Skills	Creative thinking	Using imagination to create something new—i.e. an idea, invention, work of art.
	Problem solving (critical thinking)	Recognizing and defining problems, inventing, and implementing solutions, and tracking and evaluating results.
Personal Management Skills	Self-esteem	Developing self-confidence and creating a positive self-image.
	Motivation/goal setting	Setting and meeting defined goals and objectives.
	Personal and career development	Emphasizing self-direction by establishing and implementing a plan.
Group Effectiveness Skills	Interpersonal relations	Developing ability to maintain positive relations with others.
	Negotiation	Resolving conflict between two or more individuals.
	Teamwork	Working together in a group to reach a common goal.
Influence Skills	Organizational effectiveness	Adapting to the organization's goals, values, culture, and traditional modes of operation.
	Leadership	Directing/influencing group in performance of a specific task; accepting responsibility for others.

Related Academic and Workplace Skills For *Biotechnology in Agriculture*

Task	Skill Group	Sub Skill	Description
Unit 1: Introduction to Biotechnology			
Evaluate a biotechnology news article (A.S. 1)	Foundation Skills	Reading	Comprehends written information for main ideas; draws conclusions from what is read; distinguishes between fact and opinion; uses written resources
		Writing	Applies/uses technical words and concepts; summarizes written information
Record information in a laboratory notebook (A.S. 2)	Foundation Skills	Reading	Understands drawings to obtain factual information
		Writing	Summarizes information; organizes information into an appropriate format; records data from drawings
		Science and Math	Measures in metric units; constructs table of data
Write a laboratory report (A.S. 3)	Foundation Skills	Writing	Summarizes information; organizes information into an appropriate format; makes conclusions
		Science	Constructs graph of data
Determine the effect of hand washing on microorganisms (L.S. 1)	Foundation Skills	Science	Constructs hypothesis; designs investigation; acquires and processes data; uses scientific method; uses laboratory equipment
		Writing	Records data in laboratory notebook; analyzes data, summarizes results, and makes conclusions in laboratory report
Unit 2: Genetics and Genetic Engineering			
Make a model of a DNA molecule (A.S. 1)	Foundation Skills	Science	Represents DNA form in large scale model; demonstrates understanding of basic concept of DNA
		Reading	Follows instructions to build DNA model as specified
Genetically engineer a model DNA molecule (A.S. 2)	Foundation Skills	Science	Demonstrates understanding of basic concept of genetic engineering

Task	Skill Group	Sub Skill	Description
		Reading	Follows instructions and cuts DNA model at correct locations
	Adaptability Skills	Creative Thinking	Invents new gene sequence to fit in DNA model
Extract DNA from cells (L.S. 1)	Foundation Skills	Science	Performs experiment steps as specified in kit and by instructor; acquires and processes data; uses scientific method; uses laboratory equipment
		Writing	Records data in laboratory notebook; analyzes data, summarizes results, and makes conclusions in laboratory report
Transform bacterial cells (L.S. 2)	Foundation Skills	Science	Performs experiment steps as specified in kit and by instructor; acquires and processes data; uses scientific method; uses laboratory equipment
		Writing	Records data in laboratory notebook; analyzes data, summarizes results, and makes conclusions in laboratory report
Unit 3: Impacts of Biotechnology			
Respond to concerns about biotechnology (A.S. 1)	Foundation Skills	Reading	Uses written resources; comprehends written information for main ideas; draws conclusions from what is read
		Writing	Takes notes from various sources; writes logical and understandable sentences; summarizes research; presents own opinions
Conduct an opinion poll about biotechnology (A.S. 2)	Foundation Skills	Writing	Writes appropriate survey questions; records data through surveying; analyzes data, summarizes results, and makes conclusions in final report
	Communication Skills	Oral Communication	Asks questions to obtain information; speaks clearly and effectively
		Listening	Listens for content
Write a position paper on the ethics of biotechnology (A.S. 3)	Foundation Skills	Writing	Use words appropriately; writes logical sentences; organizes sentences into paragraphs; applies rules of grammar, punctuation, capitalization, and spelling; presents own opinion

Task	Skill Group	Sub Skill	Description
Evaluate salt concentration as an environmental factor affecting plant growth (L.S. 1)	Foundation Skills	Science	Constructs hypothesis; follows steps in experiment; acquires and processes data; uses scientific method; uses laboratory equipment; monitors variables such as light and water; measures plants and supplies
		Writing	Records data in laboratory notebook; analyzes data, summarizes results, and makes conclusions in laboratory report
Unit 4: Biotechnology in Plant Science			
Design a plant culture facility for commercial use (A.S. 1)	Foundation Skills	Reading	Applies information to new situations
		Math	Draws facility to scale
	Adaptability Skills	Creative Thinking	Creates new design applying criteria specified in information sheet
Construct a still air chamber from a cardboard box (J.S. 1)	Foundation Skills	Reading	Follows written directions; uses appropriate materials and techniques as specified
Build a light stand for plant culture (J.S. 2)	Foundation Skills	Reading	Follows written directions; uses appropriate materials and techniques as specified
		Math	Takes measurements using common measuring tools; follows dimensions on plan
Demonstrate cytoplasmic inheritance of leaf variegation (L.S. 1)	Foundation Skills	Science	Performs experiment steps as specified in kit and by instructor; acquires and processes data; uses scientific method; uses laboratory equipment
		Writing	Records data in laboratory notebook; analyzes data, summarizes results, and makes conclusions in laboratory report
Demonstrate micropropagation of dry bean shoot tips (L.S. 2)	Foundation Skills	Science	Constructs hypothesis; follows steps in experiment; acquires and processes data; uses scientific method; uses laboratory equipment; monitors variables such as light and water; measures supplies
		Writing	Records data in laboratory notebook; analyzes data, summarizes results, and makes conclusions in laboratory report

Task	Skill Group	Sub Skill	Description
Demonstrate tissue culture of cauliflower (L.S. 3)	Foundation Skills	Science	Performs experiment steps as specified in kit and by instructor; acquires and processes data; uses scientific method; uses laboratory equipment
		Writing	Records data in laboratory notebook; analyzes data, summarizes results, and makes conclusions in laboratory report
Unit 5: Biotechnology in Animal Science			
Write opinion statements about concerns in animal biotechnology (A.S. 1)	Foundation Skills	Writing	Uses words appropriately; writes logical sentences; organizes sentences into paragraphs; applies rules of grammar, punctuation, capitalization, and spelling; presents own opinion
Observe antigen-antibody reactions (L.S. 1)	Foundation Skills	Science	Performs experiment steps as specified in kit and by instructor; acquires and processes data; uses scientific method; uses laboratory equipment
		Writing	Records data in laboratory notebook; analyzes data, summarizes results, and makes conclusions in laboratory report
Evaluate semen (L.S. 2)	Foundation Skills	Science	Follows steps in experiment; acquires and processes data; uses scientific method; uses laboratory equipment; compares sample to illustrations
		Writing	Records data in laboratory notebook; analyzes data, summarizes results, and makes conclusions in laboratory report
Unit 6: Microbial Biotechnology in Agriculture			
Identify foods produced by fermentation (A.S. 1)	Foundation Skills	Reading	Uses written resource (Student Supplement 1); understands tables to obtain information; comprehends written information
		Science	Explains understanding of basic biology concepts of steps in fermentation and role of microorganisms in fermentation
		Writing	Writes logical and understandable sentences; summarizes information

Task	Skill Group	Sub Skill	Description
Observe the role of microorganisms in biodegradation (L.S. 1)	Foundation Skills	Science	Constructs hypothesis; follows steps in experiment; acquires and processes data; uses scientific method; uses laboratory equipment; monitors variables such as light and water; observes role of air, culture, and microorganisms
		Writing	Records data in laboratory notebook; analyzes data, summarizes results, and makes conclusions in laboratory report
Demonstrate bacterial nitrogen fixation with inoculated clover seeds (L.S. 2)	Foundation Skills	Science	Performs experiment steps as specified in kit and by instructor; acquires and processes data; uses scientific method; uses laboratory equipment
		Writing	Records data in laboratory notebook; analyzes data, summarizes results, and makes conclusions in laboratory report

Biotechnology in Agriculture

Tools, Equipment, and Materials List

General laboratory space required for all units including the following:

Table with smooth top for a laboratory work area
Sink with hot and cold water
Electrical outlets
Bunsen burner and gas line (alcohol burners could be used instead of gas)

General laboratory equipment (large items)

Autoclave or pressure cooker to sterilize instruments
Gram scale or balance
Hot plate
Refrigerator with freezer section
Microscope with 10X, 40X, and 100X objectives
Bacterial incubator, 37°C
Water bath, 30° to 70°C
Basic laboratory glassware—beakers, graduated cylinders, and test tubes

Unit 1: Introduction to Biotechnology

Bacterial incubator, 37°C (optional)
Biotechnology news articles (teacher may have a file or students may obtain on their own)
Dish pan
Hand scrub brush
Laboratory notebook (spiral bound)
Laboratory report sheets (may be provided by teacher or developed by students)
Liquid hand soap
Marker pens
Metric ruler
Nutrient agar
Sterile petri dishes
Sterile swabs
Tap water

Unit 2: Genetics and Genetic Engineering

¼" diameter dowel, 24" long
Bacteria Colony Transformation Kit (Cabisco Biotechnology Colony Transformation Kit recommended)
Bacterial incubator, 37°C
Biological hazard bags
Block of wood—2" × 6" x 6"
Computer paper edging
DNA Extraction Kit (Carolina Biological Kit #17-1090 recommended)
Electric drill and ¼" drill bit
Marking pens, 2 (1 green, 1 black)
Pipette jar

Protractor
Refrigerator with freezer section
Scissors
Tacky glue or glue stick
Water bath, 30° to 70°C

Unit 3: Impacts of Biotechnology

Beakers
Graduated cylinders
Masking tape or plastic plant markers
News articles and research materials on biotechnology
Paper cups
Potting soil
Table salt
Viable plant seeds
Water tray

Unit 4: Biotechnology in Plant Science

⅝″ plywood, 18″ × 36″
1″ × 2″ boards, 47″ long (4)
2-bulb 48″ fluorescent shoplight
8d box nails, 20
24 hour electric timer
40% household bleach
80% ethanol
Autoclave or pressure cooker to sterilize instruments
Cauliflower tissue culture kit (Carolina Biological Cauliflower Tissue Culture Kit recommended)
Claw hammer
Cytoplasmic inheritance kit (*Wisconsin Fast Plants* Cytoplasmic Inheritance Kit #15-8796 recommended)
Dry bean seeds
Felt tip laundry marker (permanent)
Fine tip thumb forceps
Half-pint wide mouth jar
Heavy cardboard box, approximately 18″ × 16″ × 14″
Heavy duty aluminum foil, 18″ × 8′
Masking tape or parafilm
Pencils and rulers
Petri dishes, 6
Plastic packaging tape
Power saw or hand saw
Scalpel with #11 blade
Sheet of clear plastic, 1′ × 2′
Single-edge razor blade or utility knife
Spray mist bottle
Sterile distilled water
Thumb tacks

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b. *3 Field-Testing Engineered Organisms*, 1988.
c. *4 U.S. Investment in Biotechnology*, 1988.

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Biotechnology in Agriculture

Glossary

Agar — Porous gelatin-like material used as a support matrix for living cells in artificial environments

Amino acids — Organic molecules that are the building blocks of protein

Antimicrobial — Any substance that inhibits the growth of microorganisms

Aseptic — Absence of surface microorganisms such as fungi, bacteria, or algae

Autoclave (sterilizer) — A device for destroying microorganisms with the use of moist heat and pressure

Bacteria — A class of microorganisms with simple cell structure

Biological — A medical product derived from living sources, usually referring to a vaccine

Bioreactor (fermenter) — The vessel used in a fermentation process

Biosensor — A device used to detect a chemical, biological, or physical change that has a living system as one component of the device

Biotransformation — The chemical modification of organic compounds by living organisms

Bovine somatotropin (BST) — Growth-regulating hormone found in cattle; can be produced by genetically-engineered bacteria and used to increase milk production in dairy cattle

Callus — Unorganized plant tissue resulting from tissue wounding and hormone control

Carrier — Individual that can harbor an organism without developing the associated disease

Centrifuge — Device for separating substances on the basis of density

Chromosomes — Structures that primarily contain DNA and are the physical carriers of genes

Clones — Organisms or cells of nearly identical genetic makeup derived from a single source

Complementary — Containing structures that match or bond with related structures

Contaminate — To make unfit for use by introduction of undesirable organisms

Data — Facts and figures put together for information and from which conclusions can be made

Diagnostic — An agent used to detect disease

Differentiation — Acquiring different characteristics and functions as cells become more specialized in development

Disinfest — Removal of surface organisms usually by chemical agents

DNA (Deoxyribonucleic acid) — The basic substance of life; a double-stranded, filamentous molecule made up of ribose sugars, phosphoric acids, and nitrogenous bases

DNA probe — A short piece of DNA that will bind with DNA containing like sequences and be detected

Ecology — The branch of science concerned with the interrelationships of organisms and their environments

Ecosystem — The complex of a community and its environment functioning as a unit in nature

Effluent — The remaining waste liquid from a fermentation system

Electrophoresis — Technique used to separate migrating molecules in an electrical field

Embryo — Developing individual from the time of fertilization (combining of ovum and sperm) to birth

Environment — The complex of climatic, soil, and life systems that acts on an organism or an ecological community and ultimately determines its form and survival

Enzymes — Primarily protein substances that make or break chemical bonds and affect chemical reactions

Ethics/Morals — Principles of conduct governing an individual or a group about what is right or wrong

Evolution — The process of change usually referring to the development of more complex organisms from less complex

Excise — To remove a part by a process similar to cutting

Explant — Plant part that is excised and placed in culture

Expression—The appearance of a trait directed by a gene

Fermentation — The process of converting some substrate to a product through the action of a microorganism

Fungi — A group of organisms that include yeasts and molds

Gene — A piece of DNA that contains the genetic information required for the formation of a specific protein

Gene expression — Appearance or functioning of a specific trait as a result of gene action

Genetic code — A series of three nucleotide bases that determine the amino acid order and the proteins formed in cell reproduction

Genetic engineering — Technology involved in removing, modifying, or adding genes to a DNA molecule

Genetic marker — Identifiable pieces of DNA that are located near an unidentified gene; used to show the presence and transfer of the gene from one generation to the next

Genetics — Science dealing with passage of traits from one generation to another

Genetic trait — A characteristic passed from one generation to another

Genome — Complete set of chromosomes or genes present in a plant or animal

Heredity — The passage of characteristics from one generation to another

Hormones — Chemical "messengers" produced by cells in one part of an organism that have a specific effect on the activities of cells remote from the point of origin

Host — A cell or organism that harbors another organism or DNA from a foreign source

Hybrid — Offspring or cell originating from parents with differing genetic makeup

Hypothesis — An assumed conclusion made for the purpose of testing its validity in an experimental process

Inoculum — The viable cells added to begin the fermentation

Interferon — A chemical messenger of the immune system that inhibits viral replication and may have anticancer properties

In vitro — "In glass" or under laboratory or artificial conditions

In vivo — "In life" or under natural or living conditions

Legume — Class of plants characterized by their ability to bear root nodules that contain nitrogen-fixing bacteria

Ligase — Enzyme used to join pieces of DNA

Macromolecule — A large molecule (molecular weight 10^3 - 10^9) built up from smaller chemical structures (building blocks such as amino acids, simple sugars, fatty, acids, etc.)

Medium (plural-**Media**) — A mixture of nutrients used to grow tissues and cells in culture

Meristem — Actively dividing cells at growth points on plants such as shoot and root tips

Metabolism — The sum of all the chemical reactions occurring within a living cell

Microbial — Having to do with microorganisms

Microorganisms (also called microbes) — Organisms visible only with the aid of a microscope

Micropropagation — In vitro propagation; growth of plant shoot apex in a controlled artificial environment using culture vessels, aseptic conditions, and growth media

Molecular biology — The study of living processes at the level of a molecule

Molecular weight — Sum of the atomic weights of all the atoms in a molecule

Molecule — The smallest particle of a substance that still retains the properties of the substance

Monoclonal — Produced by or composed of cells derived from a single cell

Monoclonal antibody — A specific agent of immunity developed in the laboratory by fusion of a cancer cell with a cell that produces antibodies

Mutant — A cell or individual organism that differs from its parent due to a genetic change (mutation)

Mutation — A heritable change in genetic makeup

Nitrogen-fixation — Ability of certain microorganisms to convert atmospheric nitrogen to forms usable by plants

Nucleic acid — Content of the nucleus of cells (DNA and RNA) that has an acid reaction

Nucleotides — Building blocks of nucleic acid composed of a sugar, a phosphate, and a nitrogenous base

Nutrient — A substance that provides nourishment for a living organism

Organism — A living system of cells, tissues, and organs capable of independent function

Pesticide — General term for any agent used to kill undesirable organisms

Pharmaceutical — Substance that has a medically useful effect

Photosynthesis — Process of using energy from light to convert carbon dioxide (CO_2) and water (H_2O) into energy compounds usable by plants

Plant tissue culture — Growth of plants and plant parts from pieces of plants such as cells, tissues, organs, and protoplasts

Plasmid — A small (usually circular) piece of DNA that is separate from the chromosomal DNA

Plate —

a. (noun) A petri dish
b. (verb) To spread cells onto a solid nutrient medium in a petri dish

Polyclonal — Produced by or composed of cells derived from preparations containing many kinds of cells

Polymerase — An enzyme that joins nucleotides to make nucleic acids

Porcine somatotropin (PST) — A growth-regulating hormone found in pigs; can be produced by genetically-engineered bacteria and used to stimulate efficient production of lean meat

Probability — Mathematical calculation of the chance that a given event will occur

Probiotics (direct-fed microbials) — Microorganisms fed directly to animals to gain some benefit

Protein — Amino acids linked in specific arrangements to provide structural and functional elements of all living matter

Protoplast — A plant cell with the wall removed but the cell membrane intact

Reagent — A substance used to aid in detecting, measuring, preparing, or developing a product

Recombinant DNA — DNA that has been altered by genetic engineering

Recombinant DNA technology — A broad range of techniques involving the manipulation of genetic material in organisms

Regenerate — To return an altered organism to its original state

Resistant — Ability to withstand unfavorable environmental conditions

Restriction enzyme (restriction endonuclease) — Enzyme that cuts DNA strands at specific sites

Ribonucleic acid (RNA) — Single-stranded molecule of many nucleotides formed from DNA

Semen — Fluid and cells ejaculated from male reproduction organs to support living sperm

Sequence — Order of nucleotides or amino acids

Shoot apex (shoot tip) — Rapidly growing plant tip composed of meristem and underlying tissues

Somaclonal variation — A change in a plant's characteristics as a result of mutation in somatic (non-reproductive) cells

Starter cultures — Microbial cultures used in the production of fermented foods

Sterilize — To kill living microorganisms

Streak — Use of an instrument to spread out organisms on solid media in a petri dish in order to isolate colonies

Stress — A factor that has a detrimental effect on the normal growth and productivity of an organism

Substrate — The base material acted on by enzymes in the cells

Subunit vaccine — Isolation of antigenic surface proteins from disease-causing organisms and their use as a highly purified vaccine with virtually no side effects

Susceptible — Subject to the effect of a toxic or disease-producing agent

Synthesize — The production of a compound by putting together its component parts

Template — A pattern used for developing a complementary structure

Therapeutic — Relating to the treatment of disease or disorders by remedial agents or methods

Tissue — A grouping of cells of a particular kind for a particular function

Tissue culture — Growing cell clusters in media that support their growth and reproduction

Tolerance — The ability to grow and develop in otherwise unfavorable conditions

Totipotent — Ability to develop an entire plant from the genetic information in a single cell

Toxin — A poison that inhibits or stops life functions

Trait — A characteristic resulting from gene expression

Transform — To change the genetic makeup of an organism by alteration of DNA

Transgenic — Description of an individual developed through genetic engineering or gene transfer

Undifferentiated — Refers to cells that have not developed specialized functions

Vaccine — A preparation of antigenic material that stimulates an antibody response to disease-causing organisms without causing disease

Variety — A selection within a species that has identified growth and production characteristics

Vector — An agent such as a plasmid used to transfer DNA into a host cell

Vessel — A container such as a glass or plastic test tube, jar, or petri dish

Virus — Submicroscopic, noncellular particles composed of a core of nucleic acid and a protein coat; capable of reproduction only in a host cell

Introduction to Biotechnology
Unit 1

Objective Sheet

Unit Objective

After completing this unit, the student should be able to discuss basic concepts about biotechnology and be able to apply these in written and laboratory activities. The student should demonstrate these competencies by completing the assignment sheets and laboratory sheet and by scoring a minimum of 85 percent on the written test.

Specific Objectives

After completing this unit, the student should be able to:

1. Match terms related to biotechnology with their correct definitions.
2. Define biotechnology.
3. Match historical events in biotechnology with the time period in which they occurred.
4. Arrange in order the steps of the scientific method.
5. Select true statements on maintaining a laboratory notebook.
6. State purposes of maintaining a laboratory notebook.
7. Select from a list the parts of a laboratory report.
8. Select true statements about laboratory safety rules.
9. Select true statements about aseptic technique.
10. Evaluate a biotechnology news article. (Assignment Sheet 1)
11. Record information in a laboratory notebook. (Assignment Sheet 2)
12. Write a laboratory report. (Assignment Sheet 3)
13. Determine the effect of hand washing on microorganisms. (Laboratory Sheet 1)

Introduction to Biotechnology
Unit 1

Suggested Activities

Instructional Plan

1. Read the unit carefully and plan for instruction. Study the specific objectives and develop your presentation.

2. Review this unit with your school's science teaching staff. They may have facilities and equipment you can use. This may also provide opportunities for team teaching.

3. Review teaching suggestions and plan classroom and laboratory activities.

4. Plan presentation for enrichment of exceptional students as well as accommodation of special needs students.

5. Make transparencies from transparency masters included with this unit. These appear in the teacher guide only and are designed to be used with the following objectives:

   TM 1—Steps of the Scientific Method (Objective 4)
   TM 2—Laboratory Notebook (Objective 5)
   TM 3—Laboratory Report (Objective 7)

6. Obtain videotapes, pamphlets, and other material to supplement instruction of this unit. See ordering information in the suggested supplemental resources section.

7. Order laboratory equipment and materials needed to complete the laboratory activity.

8. Review instructions for evaluating student performance, and make copies of unit evaluation form.

9. Provide students with unit of instruction. Review objectives with them. Inform them about materials included in the unit test.

10. Discuss assignment sheets and laboratory sheet. Review criteria for evaluation of these activities.

11. Discuss the use of the unit evaluation form with students. Select and discuss the rating scale that will be used for student evaluation.

12. Give written test.

13. Compile assignment sheet ratings, laboratory sheet ratings, and written test scores on the unit evaluation form. Include any additional assignments.

14. Reteach and retest as required.

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Suggested Activities

Teaching Suggestions

Note: Skill areas appearing in bold face type in the teaching suggestions refer to the academic and workplace skills identified by the American Society for Training and Development (ASTD) and the U.S. Department of Labor and adapted by MAVCC.

1. Show the VHS videotape *Of the Earth: Agriculture and the New Biology* as an introduction to this unit.

2. Obtain the booklet *Of the Earth: Agriculture and the New Biology* to use as introductory material and reference.

3. Have a scientist, extension specialist, or agriculture producer discuss how biotechnology is pertinent to your geographical area.

4. Take a field trip to a biotechnology industry or research facility.

    a. You may want to videotape the tour to use with later classes, students who may have missed the trip, or for recruitment of students into your program.

    b. After returning to the classroom, ask students questions about the tour (oral discussion) or have them summarize the main points of the tour in writing.

    c. The tour reinforces **group effectiveness skills** and the follow-up discussion and review reinforces **foundation skills (writing)** and **communication skills**.

5. Discuss the importance of the scientific method with students. Refer to Teacher Supplement 1 for more information on the scientific method.

6. Collect reference materials from newspapers and magazines for student use. Sources for materials are subscriptions, libraries, science educators, and research scientists. Refer to Teacher Supplement 2 for a partial listing of magazines containing biotechnology information.

7. Assignment Sheet 1 deals with critical evaluation of news material.

    a. If time is limited, you may want to provide the students with a news article file from which to choose their articles.

    b. If more time is available, students should do their own searching for news articles. You may want to coordinate this activity with the school librarian. Researching for new information about biotechnology helps to develop students' **learning skills** and **foundation skills (reading)**.

Suggested Activities

8. Have students present their news articles from Assignment Sheet 1 to the class. Lead a class discussion about the news articles. Presentations and discussions help to improve **communication skills**. More controversial articles can lead to exciting discussions. These discussions can also improve **group effectiveness skills**.

9. Have students obtain a bound notebook and set it up for use as a laboratory notebook. This will be used in Assignment Sheet 2, Laboratory Sheet 1, and throughout this course. Show examples of acceptable notebooks.

10. Assignment Sheet 2 is a hypothetical experiment in plant fertilizer response. Students may need help interpreting some data such as "Can dead plants be evaluated as part of growth rate? What conclusions can be made about dead plants? and How significant are plant numbers?" (Suppose only one or two plants were used in each group). What other possible hypotheses might be explored as a result of this experiment?

11. Inform students about science fair projects using biotechnology information and agriscience student awards available through the FFA. These projects encourage **creative thinking** and **problem solving** and help reinforce **foundation skills (science)**. Awards improve **self-esteem** and can bring recognition to your program.

12. Have students research and report on various applications or aspects of biotechnology such as the following:

    a. Historical events in biotechnology

    b. Use of biotechnology on specific crops or livestock species

    c. Further research on topics brought up in news articles for Assignment Sheet 1

    Researching and reporting reinforces students' **learning skills** and **foundation skills** (**reading** and **writing**) and can improve student's **self-esteem** and **motivation**.

Resources Used in Developing This Unit

1. Becker, Jeffrey M., et. al. *Biotechnology: A Laboratory Course*. San Diego, CA: Academic Press, Inc., 1990.

2. Darrow, Edward E., editor. *The Science Workbook*. Columbus, OH: The Ohio State University Press, 1985.

3. Dodds, John H. and Lorin W. Roberts. *Experiments in Plant Tissue Culture*, 2nd edition. London: Cambridge University Press, 1985.

Suggested Activities

4. *Genetic Engineering of Plants*. National Research Council. Washington DC: National Academy Press. 1984.

5. Kieffer, George H. *Biotechnology, Genetic Engineering and Society*. University of Illinois at Urbana-Champaign, IL: National Association of Biology Teachers, 1987.

6. Murphy, Wendy. *The Future World of Agriculture*. Orlando, FL: Walt Disney World — Epcot Center and Grolier Inc., 1984.

Suggested Supplemental Resources

1. Videotapes (VHS or ¾")

    a. *Of the Earth: Agriculture and the New Biology*. Excellent introduction to biotechnology. Sponsored by the Monsanto Company.

    b. *Connections: Animals, People, and Technology*. Excellent introduction to biotechnology. Sponsored by the American Cyanamid Company and the Industrial Biotechnology Association.

    These videotapes are available from:

    Industrial Biotechnology Association
    1625 K Street, Northwest, Suite 1100
    Washington, DC 20006
    202-857-0244

    or

    Venard Films, Ltd.
    P.O. Box 1332
    Peoria, IL 61654
    309-699-3911

    c. *How to Prepare a Science Fair Project*,©1988. 25 min. Shows students the steps in preparing a science fair project for school, district, or state competition. (#VID4000). Available from:

    Queue, Inc.
    338 Commerce Drive
    Fairfield, CT 06430
    800-232-2224

Suggested Activities

2. Booklets

   a. *What Is Biotechnology?*

   b. *Biotechnology in Perspective*

   Available from:

   Industrial Biotechnology Association
   1625 K Street, Northwest, Suite 1100
   Washington, DC 20006
   202-857-0244

   c. *Of the Earth: Agriculture and the New Biology.* Companion booklet to video developed by the Monsanto Company. (Currently being revised.)

   Available from:

Industrial Biotechnology Association 1625 K Street, Northwest, Suite 1100 Washington, DC 20006 202-857-0244	or	Monsanto Company 800 North Lindbergh Blvd. St. Louis, MO, 63169 314-694-1000

3. "Biotechnology" unit for secondary students. Available from:

   Mathematics and Science Education Center
   University of Missouri--St. Louis
   8001 Natural Bridge Road
   St. Louis, MO 63121
   314-553-5650

Instructions For Evaluating Student Performance

Assignment Sheets — Be sure the student understands the criteria on which the evaluation is based. Assign a point value to each criterion and convert the total points to a percentage for grading.

Laboratory Sheets — Rate both process and product. The process should be based on the evaluation criteria for the laboratory activity. Observe the student during the laboratory activity and complete the rating by assigning a point value to each criterion and converting the point total to a percentage for grading. The laboratory product should be based on the completed laboratory report. Evaluation should follow the basis established in Assignment Sheet 3.

Suggested Activities

Performance evaluation can be based on the combined process and product evaluation. A suggested performance evaluation key is given below:

Performance level	Evaluation
90-100%	Skilled — Able to perform laboratory activity and arrive at a sound conclusion with no additional practice
80-90%	Moderately Skilled — Able to perform most laboratory activities and arrive at reasonable conclusions
70-80%	Limited Skill — Can perform some laboratory activities and work toward conclusions but needs additional practice in some areas
0-70%	Unskilled — Not able to follow procedure and reach a satisfactory conclusion; performance and evaluation must be repeated

Introduction to Biotechnology
Unit 1

Answers to Assignment Sheets

Assignment Sheet 1

A. Verify source of information

B. Concepts should relate to living systems and new products and processes. Content of article should be designated as "beneficial" or "dangerous" by the student.

C. Accept any opinion that has a reasonable basis. The student should make a sound choice on the approach to using the material presented. Reasons for the choice should have a logical basis.

Assignment Sheet 2

Note: The format used below is an example. Students may use other acceptable formats as long as they show essential information.

Experiment #1 — The Effect of Nitrogen Fertilizer on the Growth Rate of Wheat Seedlings

Purpose: To evaluate the effect of increasing levels of nitrogen fertilizer on plant growth rate.

Materials:
Sterile potting soil
2 in. deep peat pots, 20
Urea fertilizer (60% nitrogen)
Distilled water
Grow light (16 hours on and 8 hours off)

Plant 5 plants in each group.

Group 1 — no fertilizer

Group 2 — 1 gram of fertilizer added

Group 3 — 2 grams of fertilizer added

Group 4 — 4 grams of fertilizer added

Answers to Assignment Sheets

Observations:

WEEK 2

	# dead	plants	Height (cm)
Group 1	1	2	2.0
		2	2.5
Group 2	0	2	2.5
		3	3.0
Group 3	0	1	2.5
		4	3.0
Group 4	2	3	3.0

Remaining 3 plants in Group 4 have yellow tips on leaves.

WEEK 4

	# dead	plants	Height (cm)
Group 1	0	3	6.0
		1	7.0
Group 2	0	3	9.0
		2	10.0
Group 3	0	4	10.0
		1	11.0
Group 4	2	1	7.0

Remaining plant in Group 4 has dry and brown leaf tips.

Answers to Assignment Sheets

WEEK 6	# dead	plants	Height (cm)
Group 1	0	4	14.0
Group 2	0	5	19.0
Group 3	1	5	23.0
Group 4	1	0	0

Conclusions:

2 gram level of fertilizer shows the best growth
1 gram level of fertilizer shows good growth
4 gram level of fertilizer retards growth and kills plants

Assignment Sheet 3

The effect of increasing levels of nitrogen fertilizer on the growth rate of wheat seedlings

February 31, 2000

Kris Kringle
and
Bobby Brown

Background: I am raising wheat as an FFA project and would like to determine the best rate of nitrogen fertilizer to use for the most rapid, early growth of plants.

Problem: What is the most effective rate of nitrogen fertilizer for wheat seedlings?

Hypothesis: Wheat seedlings will grow at an increasingly rapid rate with the use of higher levels of nitrogen fertilizer.

Design: I will grow wheat seedlings in peat pots using groups of five plants. I will use four groups with the following treatments: 1 — no fertilizer, 2 — 1 gram of fertilizer, 3 — 2 grams of fertilizer, 4 — 4 grams of fertilizer. I will use urea (60% nitrogen) mixed with sterile potting soil. The plants will be maintained under a grow light with 16 hours of light and 8 hours of dark each day for the entire experiment. I will water them every third day with distilled water applied until the bottom of the peat pot is moist.

Answers to Assignment Sheets

Materials:
2 in. peat pots, 20
Sterile potting soil
Wheat seeds
Urea fertilizer
Grow light with timer
Distilled water

Procedure:

1. Make up soil and fertilizer mixtures for each group.
2. Fill 5 peat pots with the mixture for each group.
3. Plant 3 wheat seeds in each peat pot at a depth of 1/2 inch. Thin to 1 plant after germination
4. Add distilled water until the bottom of the peat pot is moist.
5. Repeat watering every third day for the entire time of the experiment.
6. Keep all peat pots under a grow light with a timer set for 16 hours on and 8 hours off.
7. Every two weeks measure the height of each plant using a metric rule measuring from soil level to the tip of the highest leaf.
8. Repeat measurements three times.

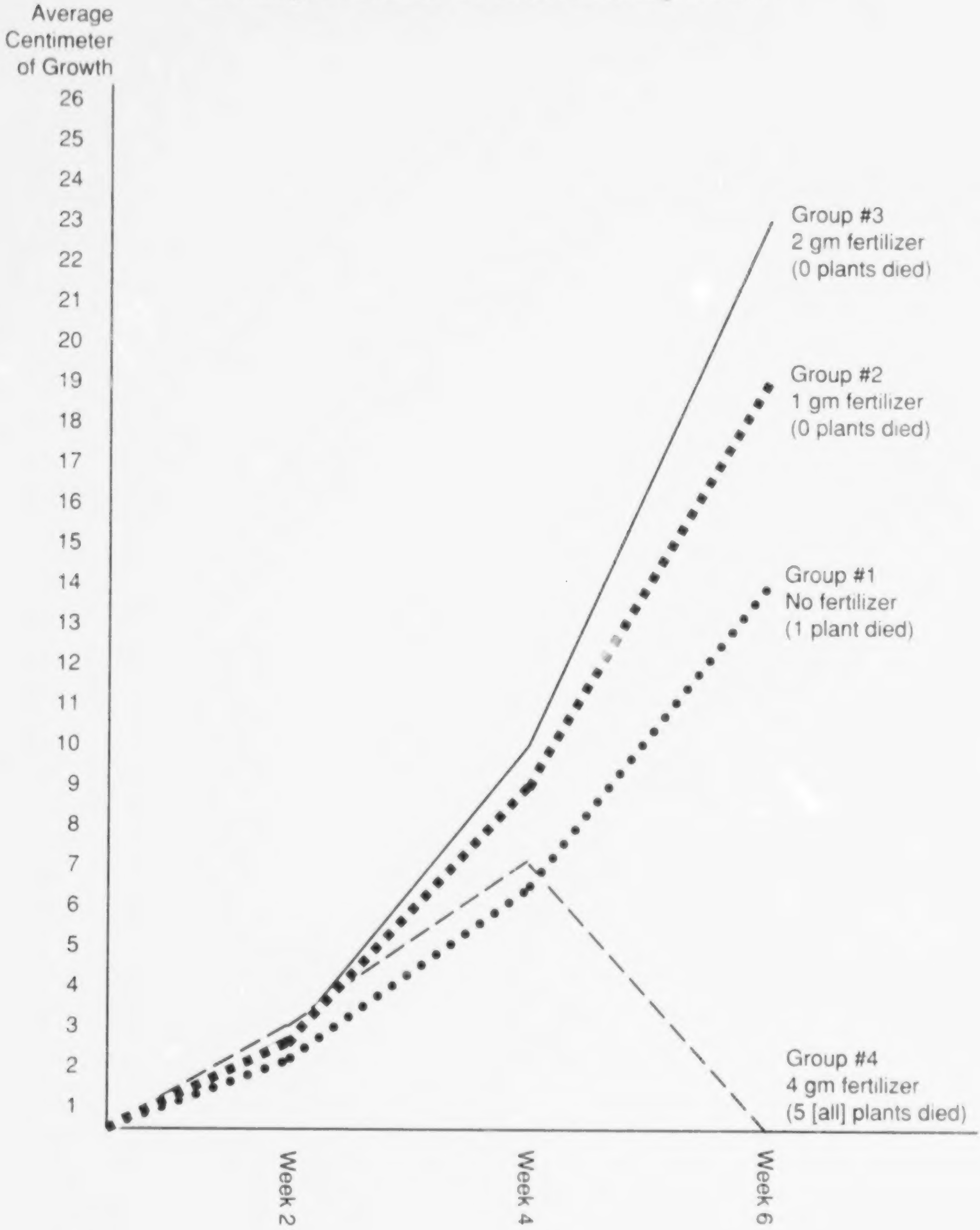
Results and Analysis:

	Week 2		Week 4		Week 6	
	# dead	Avg. height	# dead	Avg. height	# dead	Avg. height
Group 1	1	2.25cm	0	6.25cm	0	14.00cm
Group 2	0	2.80cm	0	9.40cm	0	19.00cm
Group 3	0	2.90cm	0	10.20cm	1	23.00cm
Group 4	2	3.00cm	2	7.00cm	1	0

Note: This data could also be analyzed by showing it on a graph. See the example on the following page:

Answers to Assignment Sheets

The Effect of Increasing Levels of Nitrogen Fertilizer on Wheat Seedling Growth



Answers to Assignment Sheets

Conclusions:

1. The 2 gram level of fertilizer gives the best result for rapid growth.
2. The 1 gram level of fertilizer increases growth rate but less than the 2 gram level.
3. The 4 gram rate is too heavy. It causes plants to grow at a slower rate and causes yellowing of the leaves and death.

Introduction to Biotechnology
Unit 1

Answers to Written Test

1.

a.	5	g.	6
b.	8	h.	1
c.	14	i.	4
d.	10	j.	2
e.	9	k.	7
f.	12		

2. These essential elements should be in the definition

   a. Use of living systems.
   b. A product or process results.

   In addition definitions may include:

   c. Use of microorganisms or cells
   d. Use of science and engineering principles
   e. Rearrangement of DNA
   f. Application of knowledge

3.

	Before 1800	1800 to 1900	1900 to 1977	1977 to Present
a.			X	
b.		X		
c.			X	
d.				X
e.				X
f.	X			
g.		X		
h.				X
i.			X	
j.		X		

Answers to Written Test

4.	a.	6	e.	8
	b.	2	f.	5
	c.	7	g.	4
	d.	3	h.	1

5. The following are marked with an "X" — c, e

6. Any two of the following:

   a. Provides a permanent record of all activities in the laboratory as they are accomplished.
   b. Provides an information base for continuation of experiments or development of new experiments.
   c. Provides information for explanation of results or reasons for unexpected or unexplainable results.
   d. Provides a record for use of data for other experiments and comparison of results.
   e. Provides a source of historical information for use in the future.
   f. Can be used as a legal document for proof of experimentation and results.

7. The following are marked with an "X" — a, c, d, e, f, h

8. The following are marked with an "X" - - b, d, e, f, h, j, k, l

9. The following are marked with an "X" — a, b, c, d, g, h, j, k

Introduction to Biotechnology
Unit 1

Written Test

Name ______________________________ Score ______________

1. Match the terms on the right with the correct definitions.

______a. Primarily protein substances that make or break chemical bonds and affect chemical reactions

______b. The passage of characteristics from one generation to another

______c. Amino acids linked in specific arrangements to provide structural and functional elements of all living matter

______d. Organisms visible only with the aid of a microscope

______e. An assumed conclusion made for the purpose of testing its validity in an experimental process

______f. The smallest particle of a substance that still retains the properties of the substance

______g. The production of some chemical or biological compounds by action of microorganisms

______h. Organic molecules that are the building blocks of protein

______i. The basic substance of life; a double-stranded, filamentous molecule made up of ribose sugars, phosphoric acids, and nitrogenous bases

______j. A class of microorganisms with simple cell structure

______k. A piece of DNA that contains the genetic information required for the formation of a specific protein

1. Amino acids
2. Bacteria
3. -cide
4. DNA
5. Enzymes
6. Fermentation
7. Gene
8. Heredity
9. Hypothesis
10. Microorganisms
11. Molecular biology
12. Molecule
13. Organism
14. Protein
15. RNA
16. Virus

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Written Test

2. Define biotechnology. Include all the essential elements to make your definition complete.

____

____

____

3. Match the historical event in biotechnology with the proper time period by placing an "X" in the correct column.

Event	Before 1800	1800 to 1900	1900 to 1977	1977 to Present
a. James Watson and Francis Crick solve the molecular structure of DNA				
b. Luther Burbank develops new varieties of hybrid plants by selective crossbreeding				
c. Paul Berg moves a functioning piece of DNA from one organism to another				
d. Bacteria is being engineered to produce specific vaccination agents to protect animals from disease				
e. Herbicide-resistant plants are being developed by moving genes from one plant to another				
f. Fermentation is first used as a means of preserving food and adding alcohol content				
g. Gregor Mendel discovers that genetic traits are passed from one generation to another				
h. Bacteria are being engineered that are capable of breaking down toxic material				

Written Test

	Event	Before 1800	1800 to 1900	1900 to 1977	1977 to Present
i.	Marshall Nirenberg and Severo Ochoa determine that the "genetic code" uses a sequence of three bases to direct the formation of a specific amino acid				
j.	Louis Pasteur discovers that microorganisms cause fermentation and disease				

4. Arrange in order the steps of the scientific method by numbering them from 1 through 8.

a. ______ Collect data

b. ______ Research available information

c. ______ Make your conclusions

d. ______ Formulate a hypothesis

e. ______ Write a laboratory report

f. ______ Write a proposal

g. ______ Design your investigation

h. ______ Identify the problem

5. Select true statements on maintaining a laboratory notebook by placing an "X" in the blanks next to the true statements.

______a. The cover is only used to identify the teacher of the class.

______b. An index is optional.

______c. Each laboratory activity should be recorded including the date, workers, purpose, equipment, procedure, data, and conclusions.

______d. The notebook should be loose-leaf so pages can be added or removed as needed.

______e. Records must be legible.

______f. Errors should be erased carefully and thoroughly.

Written Test

6. State two purposes of maintaining a laboratory notebook.

   a. ____

   b. ____

7. Select parts of a laboratory report from the list by placing an "X" in the correct blanks.

   ______a. Experimental design

   ______b. Publication date

   ______c. Conclusions

   ______d. Introduction

   ______e. Table of contents

   ______f. Heading information such as date and name

   ______g. Copyright

   ______h. Results and analysis

   ______i. Bibliography

8. Select true statements about laboratory safety rules by placing an "X" next to the true statements.

   ______a. Use chewing gum to help purify laboratory air.

   ______b. Wear safety glasses and protective clothing for spills.

   ______c. Bring only your procedure sheets, reference material, laboratory notebook, and pen into the laboratory area.

   ______d. Wash your hands before and after each session.

   ______e. Do not use laboratory equipment without permission from your instructor.

   ______f. Become familiar with the laboratory procedure before entering the laboratory area.

   ______g. Light the burners, and then call the instructor over for inspection.

   ______h. Turn in all used materials and containers to the instructor.

Written Test

______i. Only disinfect your work area after a laboratory session, not before.

______j. Do not try to disrupt others' work.

______k. Immediately report any spills, accidents, or injuries to the instructor.

______l. Label all chemical containers and culture vessels.

9. Select true statements about aseptic technique by placing an "X" next to the true statements.

______a. Do not touch anything except the instruments and materials in the clean work area.

______b. Disinfect your hands by spraying them with 70% ethanol.

______c. Scrub your hands, nails, fingers, and arms to the elbows for several minutes using warm water and soap.

______d. Disinfect instruments between each step of the procedure.

______e. Disinfect the work surface with a 10% hydrochloric acid solution.

______f. Use only instruments and materials that have been washed in detergent and warm water.

______g. Allow your hands to dry in the open air by holding them up and gently moving them back and forth.

______h. Control air movement over the work area by working in an enclosed chamber or with millipore-filtered air.

______i. Remove all used materials from the work area after you complete the experiment.

______j. Avoid breathing, coughing, or sneezing directly into the clean work area.

______k. Move your hands around rather than over unprotected materials in the work area.

______l. Work directly over your materials so you can observe all the details.

***Permission to duplicate this test is granted.**

Introduction to Biotechnology
Unit 1

Unit Evaluation Form

Student Name ______________________________ Unit Rating __________

Assignment Sheet 1—Evaluate a Biotechnology News Article Rating _____

Comments: ______________________________

____

Assignment Sheet 2—Record Information in a Laboratory Notebook Rating _____

Comments: ______________________________

____

Assignment Sheet 3—Write a Laboratory Report Rating _____

Comments: ______________________________

____

Laboratory Sheet 1—Determine the Effect of Hand Washing on Microorganisms Rating _____

Comments: ______________________________

____

Written Test Scores

Pretest _____ Posttest _____ Other _____

Other ______________________________

____

Teacher Signature ______________________________ Date __________

Student Signature ______________________________ Date __________

***Permission to duplicate this form is granted.**

Introduction to Biotechnology
Unit 1

Teacher Supplement 1—The Scientific Method

Note: The scientific method will be used in laboratory activities throughout the entire course. You may wish to emphasize the importance of this procedure by using information in this supplement.

A. The scientific method is a "thought process" to guide investigators through experimental studies to arrive at sound conclusions.

B. There are many variations to scientific methodology but all have these in common:

    1. Determination of a possible outcome (hypothesis)
    2. Experimental process to test a hypothesis
    3. Conclusions determining the validity of the hypothesis

C. Emphasis needs to be placed on honest conclusions based on valid experimental procedures. Results should be repeatable in other experiments.

D. Factual scientific results require verification of hypothetical proposals by repeated testing. At times a widely believed concept is changed after considerable testing.

Example: At one time it was widely believed that the Earth was flat.

Introduction to Biotechnology
Unit 1

Teacher Supplement 2—Sources for Biotechnology Information (partial listing)

1. Agricultural magazines such as *Farm and Ranch Guide* and *Farm Journal*
2. Local and national newspapers and news magazines
3. Agricultural extension service and experiment station releases. Most states have a bi-monthly bulletin of farm research.
4. Industry publications such as *Kernels* from Pioneer Hi-Bred International Inc.
5. USDA Publications
   a. *Agricultural Research* available from: Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402-9325
   b. *Biotechnology Notes* available from: USDA/OAB, Room 321-A, Admin. Bldg., 14th and Independence Avenue Southwest, Washington, DC 20250
6. *Ag Consultant*, Meister Publishing Company, 37733 Euclid Avenue, Willoughby, OH 44094
7. *Science of Food and Agriculture*, Council for Agricultural Science and Technology (CAST), 137 Lynn Avenue, Ames, IA 50010-7197
8. *Scientific American*, P.O. Box 3186, Harlan, IA 51593-2377
9. *Science* magazine, 1515 Broadway, New York, NY 10109-0163
10. *Discover* magazine, P.O. Box 359087, Palm Coast, FL 32035-9944
11. *Bio/Technology*, P.O. Box 1721, Riverton, NJ 08077-9721
12. *American Biotechnology Laboratory*, P.O. Box 3115, Woburn, MA 01888-9915
13. *AgBiotechnology News Magazine*, P.O. Box 7, Cedar Falls, IA 50613. Phone: 319-277-3599.

Steps of the Scientific Method

a. Identify the problem.

b. Research available information.

c. Formulate a hypothesis.

d. Design your investigation.

e. Write a proposal.

f. Collect data.

g. Make your conclusions.

h. Write a laboratory report.

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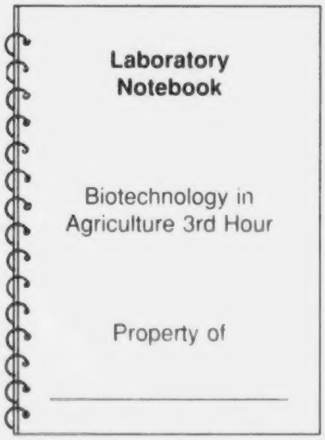
Laboratory Notebook



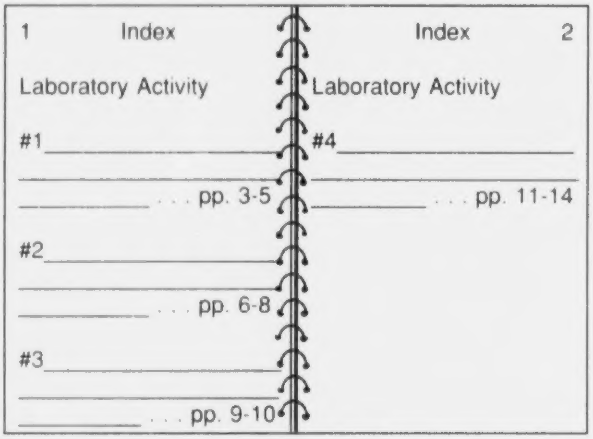
Laboratory Notebook

Biotechnology in Agriculture 3rd Hour

Property of

____

Cover



1 Index

Laboratory Activity

#1______________

______________ . . . pp. 3-5

#2______________

______________ . . . pp. 6-8

#3______________

______________ . . . pp. 9-10

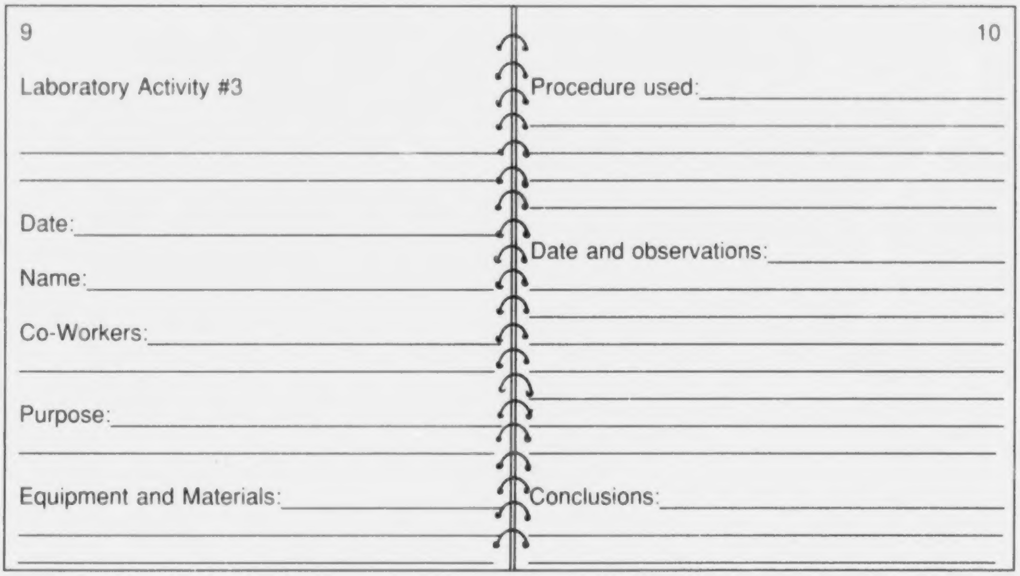
Index 2

Laboratory Activity

#4______________

______________ . . . pp. 11-14

Index Pages



9

Laboratory Activity #3

Date:______________

Name:______________

Co-Workers:______________

Purpose:______________

Equipment and Materials:______________

10

Procedure used:______________

Date and observations:______________

Conclusions:______________

Record of Activity

Laboratory Report

Title of experiment:

Date of report:

Name of writer:

Co-workers:

-1-

Introduction:

Experimental design:

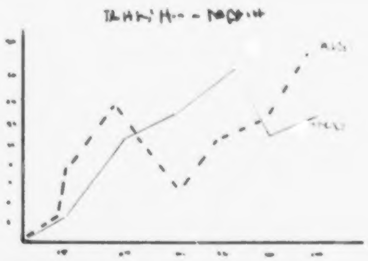
Materials and equipment:

-2-

Procedure:

Results and Analysis:

-3-



Conclusions:

-4-

Introduction to Biotechnology
Unit 1

Information Sheet

1. **Terms and definitions**

    a. **Amino acids** — Organic molecules that are the building blocks of protein

    b. **Bacteria** — A class of microorganisms with simple cell structure

    Note: *Bacterium* is the singular form; *Bacteria* is plural.

    c. **-cide** — A suffix meaning "to kill"

    Examples: Bactericide—an agent that kills bacteria. Fungicide—an agent that kills fungus. Herbicide—an agent that kills plants. Insecticide—an agent that kills insects.

    d. **DNA (Deoxyribonucleic acid)** — The basic substance of life; a double-stranded, filamentous molecule made up of ribose sugars, phosphoric acids, and nitrogenous bases

    e. **Enzymes** — Primarily protein substances that make or break chemical bonds and affect chemical reactions

    f. **Fermentation** — The production of some chemical or biological compounds by action of microorganisms

    g. **Gene** — A piece of DNA that contains the genetic information required for the formation of a specific protein

    Note: The gene is called the basic unit of heredity.

    h. **Heredity** — The passage of characteristics from one generation to another

    i. **Hypothesis** — An assumed conclusion made for the purpose of testing its validity in an experimental process

    j. **Microorganisms (also called microbes)** — Organisms visible only with the aid of a microscope

    k. **Molecular biology** — The study of living processes at the level of a molecule

    l. **Molecule** — The smallest particle of a substance that still retains the properties of the substance

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Information Sheet

m. **Organism** — A living system of cells, tissues, and organs capable of independent function

n. **Protein** — Amino acids linked in specific arrangements to provide structural and functional elements of all living matter

o. **Virus** — Submicroscopic, noncellular particles composed of a core of nucleic acid and a protein coat; capable of reproduction only in a host cell

2. Definitions of biotechnology

Note: Biotechnology has several definitions depending on different points of view.

a. The use of microorganisms, animal cells, plant cells, or components of cells such as enzymes to produce products or carry out processes for human benefit

Note: This definition will be used in this course.

b. Bio—life; technology—the application of knowledge for practical use

c. The use of biological processes to manufacture products

d. A group of interrelated fields of study concerned with products and processes in living systems

e. The application of scientific and engineering principles to the processing of materials by biological agents to provide goods and services

f. The science involved in rearranging genetic material (DNA) to create new products and processes

g. The use of living organisms to make commercial products

3. History of biotechnology

a. Early discoveries — before 1800

Note: These early discoveries have become common methods still used today.

- Fermentation was used as a means of preserving food and adding alcohol content.
- Yeast was used to make bread rise.
- Milk was fermented to make cheese.
- Plants and animals were domesticated (tamed).

Information Sheet

- Superior plants and animals were selected for breeding.
- Anton Van Leeuwenhoek developed microscopic technology and made accurate descriptions of microscopic life forms and structures.

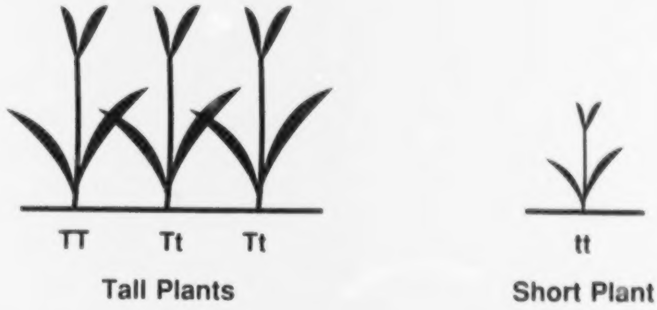
b. Basic scientific discoveries — 1800 to 1900

Note: This is an era of scientific "awakening" when significant discoveries were made that became the basis for future biotechnology.

- Charles Darwin proposed that inherited changes affect the evolution of populations.
- Gregor Mendel discovered that genetic traits are passed from one generation to another.

Figure 1—Mendel's 3:1 Ratio of Inheritance (Simple Dominance)

T = Tall Plants
t = Short Plants



- Louis Pasteur discovered that microorganisms cause fermentation and disease. Originated vaccine use for disease prevention.
- Frederic Miescher isolated DNA from the nuclei of cells and others worked out its basic chemical makeup.
- Luther Burbank developed new varieties of hybrid plants by selective crossbreeding.
- George Washington Carver discovered many new uses for plant products.

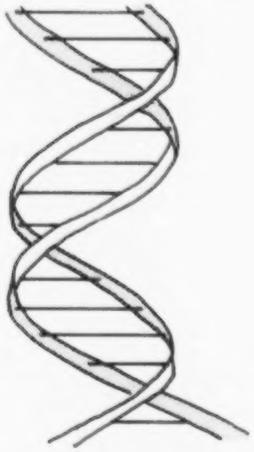
Information Sheet

c. Discoveries in molecular biology — 1900 to 1977

Note: Scientists made discoveries about life at the basic level that lead to the ability to recombine DNA to make new products.

- Mendel's rules of inheritance were verified at the molecular level and applied to many living systems.
- George Beadle and Edward Tatum discovered that each gene directs the formation of a specific protein.
- James Watson and Francis Crick solved the molecular structure of DNA.

Figure 2—Model of DNA structure



- Marshall Nirenberg and Severo Ochoa determined that the "genetic code" uses a sequence of three bases to direct the formation of a specific amino acid.
- Paul Berg moved a functioning piece of DNA from one organism to another.
- Stanley Cohen moved a functioning gene from one organism to another.
- Scientists learned how to grow cells in culture vessels in order to study them in detail.
- Scientists discovered how to preserve cells by freezing and return them to activity by thawing. (Basis for artificial insemination)

Information Sheet

d. The age of biotechnology — 1977 to present

Note: This age began when the first useful product was produced as a result of recombining DNA. Most products have been developed since 1984.

- Herbicide-resistant plants are developed by moving genes from one plant to another.
- Disease and insect-resistant plants are developed by genetic engineering.
- Plants manufacture their own insecticide after gene transfer from bacteria.
- Bacteria are altered to protect plants from frost damage.
- Bacteria are engineered to produce hormones that control growth rate, increase milk production, and improve meat quality.
- Engineered bacteria produce specific vaccination agents to protect animals from disease.
- Human insulin is produced in purified form by altered bacteria.
- Engineered bacteria are developed that are capable of breaking down toxic materials.
- Engineered bacteria produce chemicals that are used to stop heart attacks and control blood pressure.

Figure 3—Biotechnology product helps treat heart-attack victim

Information Sheet

4. Steps of the scientific method

Figure 4—Scientific Method

Note: Examples used in this section apply to Assignment Sheet 2.

a. **Identify the problem** — Start broad and then narrow to a specific problem that can be explored in a reasonable experiment or set of experiments.

Example: Broad problem — What is the effect of fertilizer on plants? Narrow to — What is the effect of nitrogen fertilizer on wheat seedlings?

b. **Research available information** — Review laboratory procedures and library information about your problem.

Example: Libraries with agricultural research information have cataloged information on nitrogen fertilizer use in wheat seedlings. This information can help you design an experiment and compare your results to others.

c. **Formulate a hypothesis** — Write a statement to be proved or disproved that includes a possible result.

Example: Wheat seedlings treated with high levels of nitrogen fertilizer will grow at a faster rate than untreated or low level treated seedlings.

d. **Design your investigation** — Write detailed steps so that someone else could repeat your experiment.

Example: Put wheat seedlings into 4 groups; 1 with no fertilizer and the other 3 groups with increasing levels of nitrogen fertilizer. Put 5 plants in each group so you have enough for reliable results.

Information Sheet

e. **Write a proposal** — State how you plan to conduct your experiment.

Example: I plan to plant seedlings in peat pots and potting soil and measure their growth rate every 2 weeks. I plan to mix 100 grams of soil with 0, 1, 2, and 4 grams of urea fertilizer containing 60% nitrogen. I will maintain the plants under 16 hours of daily light and adequate water.

f. **Collect data** — Run the experiment and record all information and observations in your laboratory notebook.

Example: Prepare a chart and record the height of the longest leaf from the surface of the soil to the tip of the leaf. Record at 2 weeks and repeat at 4 and 6 weeks. Record any other information such as death or leaf discoloration.

g. **Make your conclusions** — Explain the results and determine if your hypothesis is correct.

Example: Determine if wheat seedlings grew faster as fertilizer level increased. Charts or graphs are often good means of illustrating results. Make conclusions about any unexpected occurrences.

h. **Write a laboratory report**

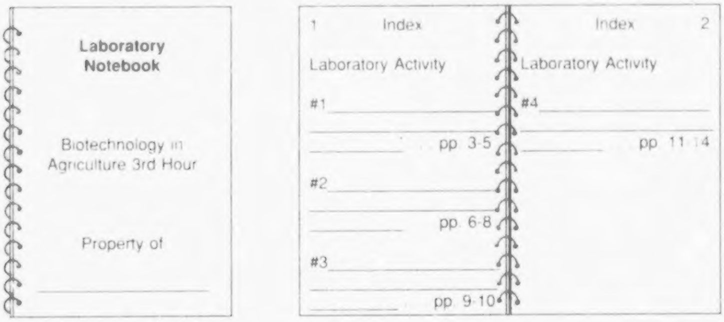
Note: Follow the outline in Information Sheet, part 7.

5. **Maintaining a laboratory notebook**

a. Essential information to be kept in a laboratory notebook

- Cover to identify the laboratory notebook and owner
- Index pages to record activities and page numbers from the notebook

Figure 5—Example of Laboratory Notebook—Cover and Index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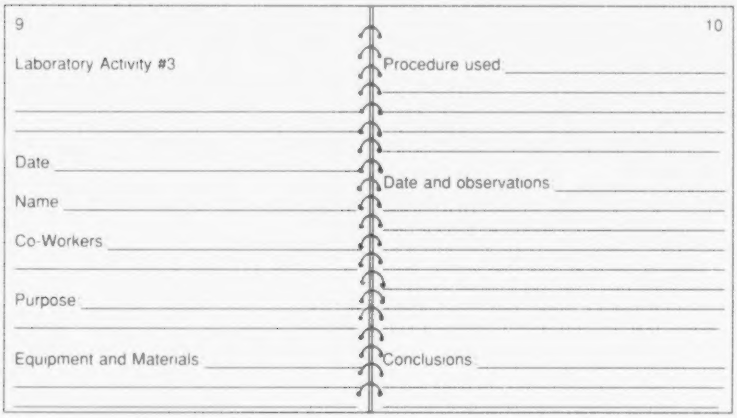
#4
pp. 11-14

Information Sheet

- Title, date, name of primary investigator, and names of co-workers
- Short statement of the purpose of the experiment
- List of the equipment and materials used
- Description of the procedure used
- Record of data collected and observations about the activity
- Statement of the conclusions reached

Figure 6—Example of Laboratory Notebook



9

Laboratory Activity #3

Date

Name

Co-Workers

Purpose

Equipment and Materials

10

Procedure used

Date and observations

Conclusions

b. Requirements for a valid laboratory notebook

- Notebook is permanently bound so pages cannot be removed.
- Records are maintained in legible form and kept up-to-date.
- Records are made in ink so alterations are not possible.
- Errors are lined out and initialed with an explanation if needed.
- Notebook is kept free of damage and stored in a safe place.

Information Sheet

6. Purposes of maintaining a laboratory notebook

a. Provides a permanent record of all activities in the laboratory as they are accomplished.

b. Provides an information base for continuation of experiments or development of new experiments.

c. Provides information for explanation of results or reasons for unexpected or unexplainable results.

d. Provides a record of data which can be used for other experiments and comparison of results.

e. Provides a source of historical information for use in the future.

f. Can be used as a legal document for proof of experimentation and results.

7. Writing a laboratory report

a. **Heading information**

- Title of experiment
- Date of report
- Name of writer
- Names of others working on the experiment

b. **Introduction**

- Background information on why the experiment is being done
- Statement of the problem worked on
- Hypothesis

c. **Experimental design**

- Materials and equipment used
- Procedure that was followed

d. **Results and analysis** — Data in easily readable form such as tables, charts, graphs, or lists presented so they can be interpreted for meaning (analysis)

Information Sheet

e. **Conclusions** — Interpretation of the results explaining how the experiment proved or disproved your hypothesis

f. **Supplemental information** (if needed)

- Glossary—Definitions of specialized terms used in the experiment
- Appendix—Additional information about the experiment from outside sources

Note: Formal reports, science fair projects, and FFA Agriscience Award Applications may require additional information.

8. **Laboratory safety rules**

a. Become familiar with the laboratory procedure before entering the laboratory area.

b. Do not eat, drink, or chew in the laboratory area.

c. Do not try to disrupt others' work.

d. Do not use laboratory equipment without permission from your instructor.

e. Wear safety glasses and protective clothing for spills or stains.

f. Bring only your procedure sheets, laboratory notebook, and recording pen into the laboratory area.

g. Wash your hands before and after each session.

h. Disinfect your work area before and after each session.

i. Label all chemical containers and culture vessels.

j. Light burners only after instructor approval, and turn them off immediately after use.

k. Turn in all used materials and containers to the instructor.

l. Immediately report any spills, accidents, or injuries to the instructor.

Information Sheet

9. Aseptic technique

Note: Aseptic technique is a method to maintain the work area free of undesirable organisms, which are referred to as contaminants.

a. Control air movement over the work area by working in an enclosed chamber or with millipore-filtered air.

b. Disinfect the work surface with a 10% household bleach solution.

Note: Many experimental protocols refer to household bleach as sodium hypochlorite ($NaHCO_3$). Actually household bleach is only 4% $NaHCO_3$. A 10% solution of household bleach is made by mixing 9 parts of water with 1 part of bleach.

c. Spray the work surface and instruments with 70% ethanol and allow to air dry.

d. Scrub your hands, nails, fingers, and arms to the elbows for several minutes using warm water and liquid hand soap.

e. Allow your hands to dry in the open air by holding them up and gently moving them back and forth.

f. Disinfect your hands by spraying them with 70% ethanol, and allow them to air dry.

g. Do not touch anything except the instruments and materials in the clean work area.

h. Use only instruments and materials that have been sterilized (autoclaved) or disinfected.

i. Avoid breathing, coughing, or sneezing directly into the clean work area.

j. Position all materials and instruments toward the back of the work chamber.

k. Do not lean over or work with your face close to the work area.

l. Move your hands around rather than over unprotected materials in the work area.

m. Disinfect instruments between each step of the procedure.

n. Remove all used materials from the work area immediately after you finish using them.

o. Remove all materials from the work area after each session and disinfect the area with 10% household bleach.

Introduction to Biotechnology
Unit 1

Student Supplement 1—Glossary of Additional Terms

1. **Autoclave (sterilizer)** — A device for destroying microorganisms with the use of moist heat and pressure
2. **Bovine somatotropin (BST)** — Growth-regulating hormone found in cattle; can be produced by genetically-engineered bacteria and used to increase milk production in dairy cattle
3. **Chromosomes** — Structures that primarily contain DNA and are the physical carriers of genes
4. **Data** — Facts and figures put together for information and from which conclusions can be made
5. **Disinfest** — Removal of surface organisms usually by chemical agents
6. **Evolution** — The process of change usually referring to the development of more complex organisms from less complex
7. **Genetic code** — Sequences of three nucleotide bases in DNA that direct the formations of specific amino acids
8. **Genetic engineering** — Alteration of the characteristics of an organism by inserting genes from another organism into its DNA
9. **Genetic trait** — A characteristic passed from one generation to another
10. **Hormone** — Chemical "messenger" produced in one part of an organism that affects activities in another part
11. **Hybrid** — Offspring from two parents that have different genetic makeups
12. **Interferon** — Chemical messenger of the immune system that inhibits reproduction of viruses and may have anti-cancer properties
13. **Medium** (plural-**Media**) — A mixture of nutrients used to grow tissues and cells in culture
14. **Monoclonal antibody** — A specific agent of immunity developed in the laboratory by fusion of a cancer cell with a cell that produces antibodies
15. **Nucleic acid** — Content of the nucleus of cells (DNA and RNA) that has an acid reaction

Student Supplement—1

16. **Nucleotides** — Building blocks of nucleic acid composed of a ribose sugar, a phosphate, and a nitrogenous base

17. **Organism** — A group of cells, tissues, and organs which form a functioning, living unit

18. **Plate** —

    a. (noun) A petri dish
    b. (verb) To spread cells onto a solid nutrient medium in a petri dish

19. **Porcine somatotropin (PST)** — A growth-regulating hormone found in pigs; can be produced by genetically-engineered bacteria and used to stimulate efficient production of lean meat

20. **Recombinant DNA technology** — A broad range of techniques involving the manipulation of genetic material in organisms

21. **Ribonucleic acid (RNA)** — Single-stranded molecule of many nucleotides formed from DNA

22. **Sterilize** — To kill living microorganisms

23. **Streak** — Use of an instrument to spread out organisms on solid media in a petri dish in order to isolate colonies

24. **Tissue** — A grouping of cells of a particular kind for a particular function

25. **Tissue culture** — Growing cell clusters in media that support their growth and reproduction

26. **Variety** — Group of plants within a species that shows distinct characteristics

Introduction to Biotechnology
Unit 1

Assignment Sheet 1—Evaluate a Biotechnology News Article

Name ______________________ Overall Rating __________

Evaluation criteria	**Rating**
Article identified	______
Analysis complete	______
Author's ideas presented	______
Opinion supported by fact	______
Conclusion is logical	______

Introduction: The purpose of this assignment is to familiarize the student with news coverage about biotechnology and to evaluate that coverage.

Directions: Find an article about biotechnology in a newspaper, magazine, or other published material. Complete all of the following information. Attach a copy of the article.

A. Identification of source

1. Author of the article ______________________

____

2. Title of the article ______________________

____

3. Name of publication ______________________

____

4. Date of publication ______________________

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Assignment Sheet 1

B. Analysis of the article

1. What are the biotechnology concepts presented in the article?

2. Are these presented as "beneficial" or "dangerous" concepts?

C. Evaluation of the author

1. Do you feel the material was presented as opinion or fact? Explain your choice.

2. Explain fully why you agree or disagree with the author.

Introduction to Biotechnology
Unit 1

Assignment Sheet 2—Record Information in a Laboratory Notebook

Name ______________________________ Overall Rating __________

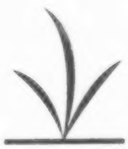
Evaluation criteria	Rating
Notebook cover completed	______
Index pages set up correctly	______
Experiment title and information completed	______
Purpose explained	______
Equipment and material listed	______
Procedure described	______
Data and observations completed	______
Conclusions complete	______
Experiment recorded in index	______

Introduction: The purpose of this assignment is to gain experience in maintaining a laboratory notebook. The same process will be used in all laboratory experiments throughout this course and is patterned after those used in work situations. This assignment will get you started by providing experimental results for you to record.

A. Obtain a bound notebook and set it up by following the steps in the information sheet. Use the examples in the information sheet for making your notebook entries.

B. Make a chart in your laboratory notebook data page and record the heights of the plants in centimeters using the drawings that follow.

Week 2 **No Fertilizer**



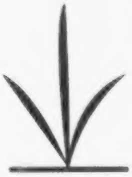
2 Plants

2 Plants

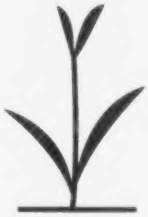
1 Plant Died

Assignment Sheet 2

Week 2 **1 Gram Fertilizer**

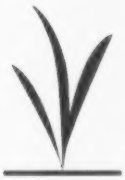


2 Plants

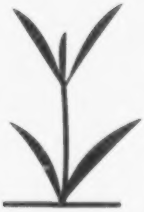


3 Plants

Week 2 **2 Grams Fertilizer**

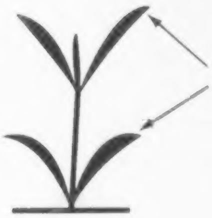


1 Plant



4 Plants

Week 2 **4 Grams Fertilizer**



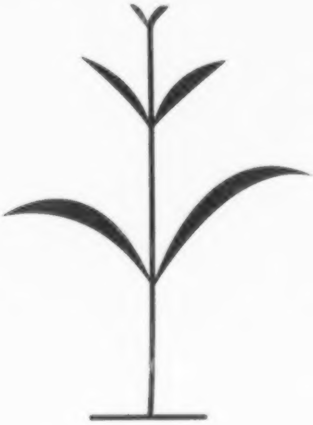
Yellow Tips on Leaves

3 Plants

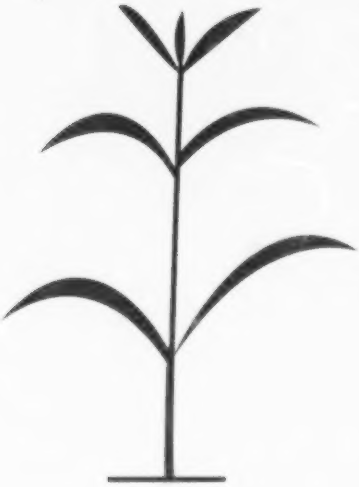
2 Plants Died

Assignment Sheet 2

Week 4 **No Fertilizer**

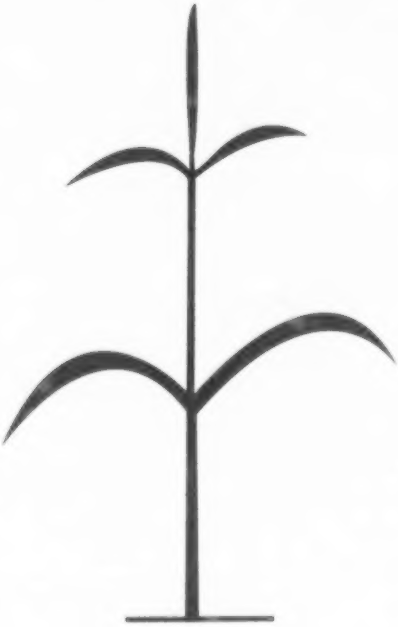


3 Plants

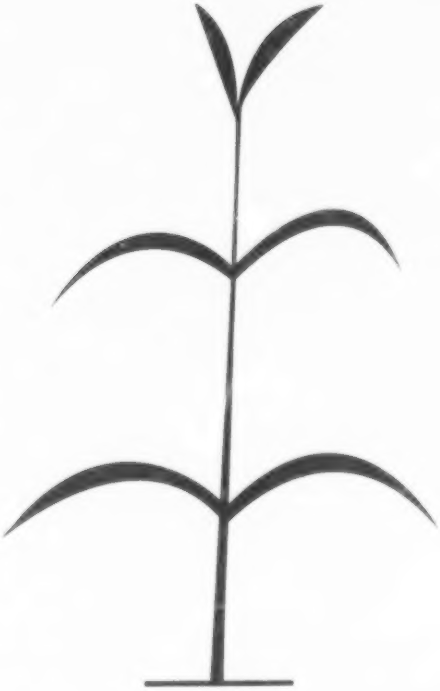


1 Plant

Week 4 **1 Gram Fertilizer**



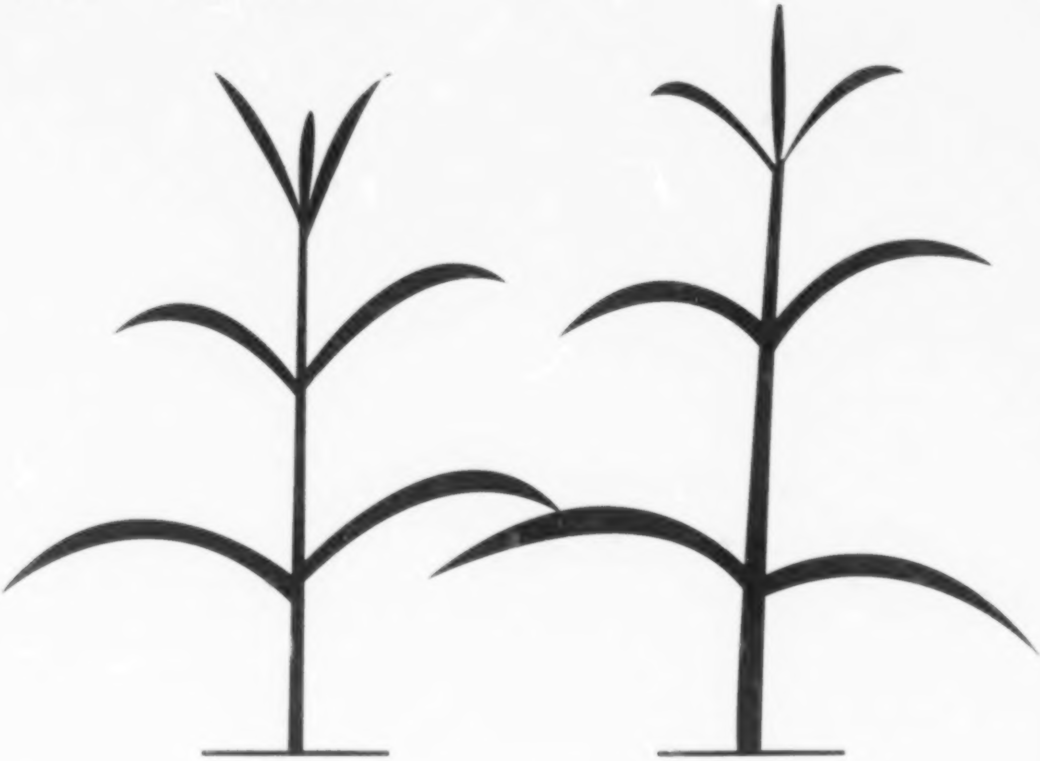
3 Plants



2 Plants

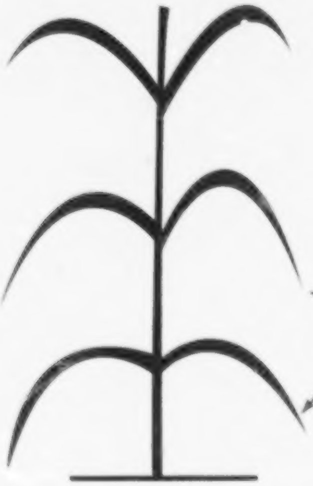
Assignment Sheet 2

Week 4 **2 Grams Fertilizer**


4 Plants
1 Plant

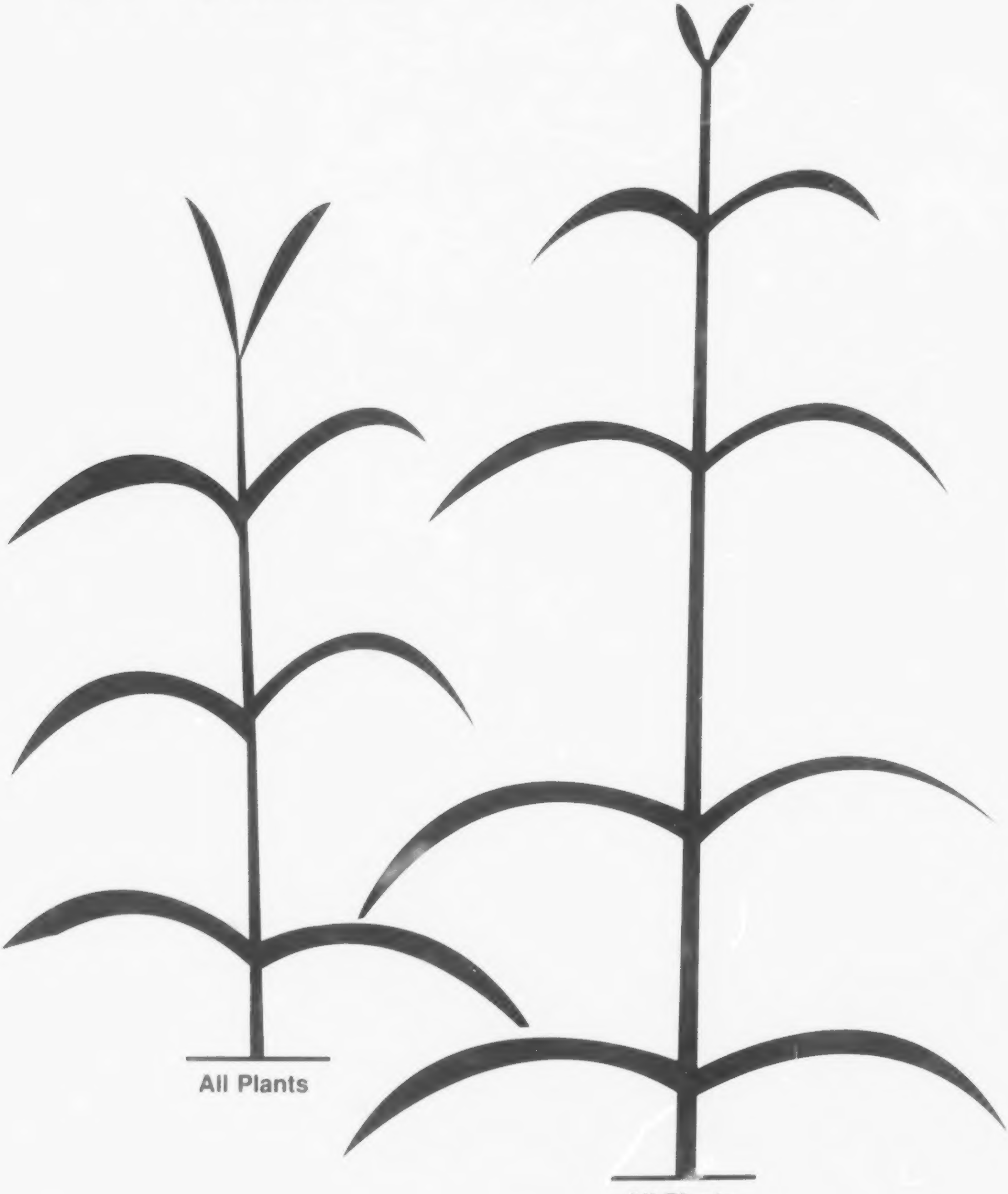
Assignment Sheet 2

Week 4 **4 Grams Fertilizer**


Leaf Tips Dry and Brown

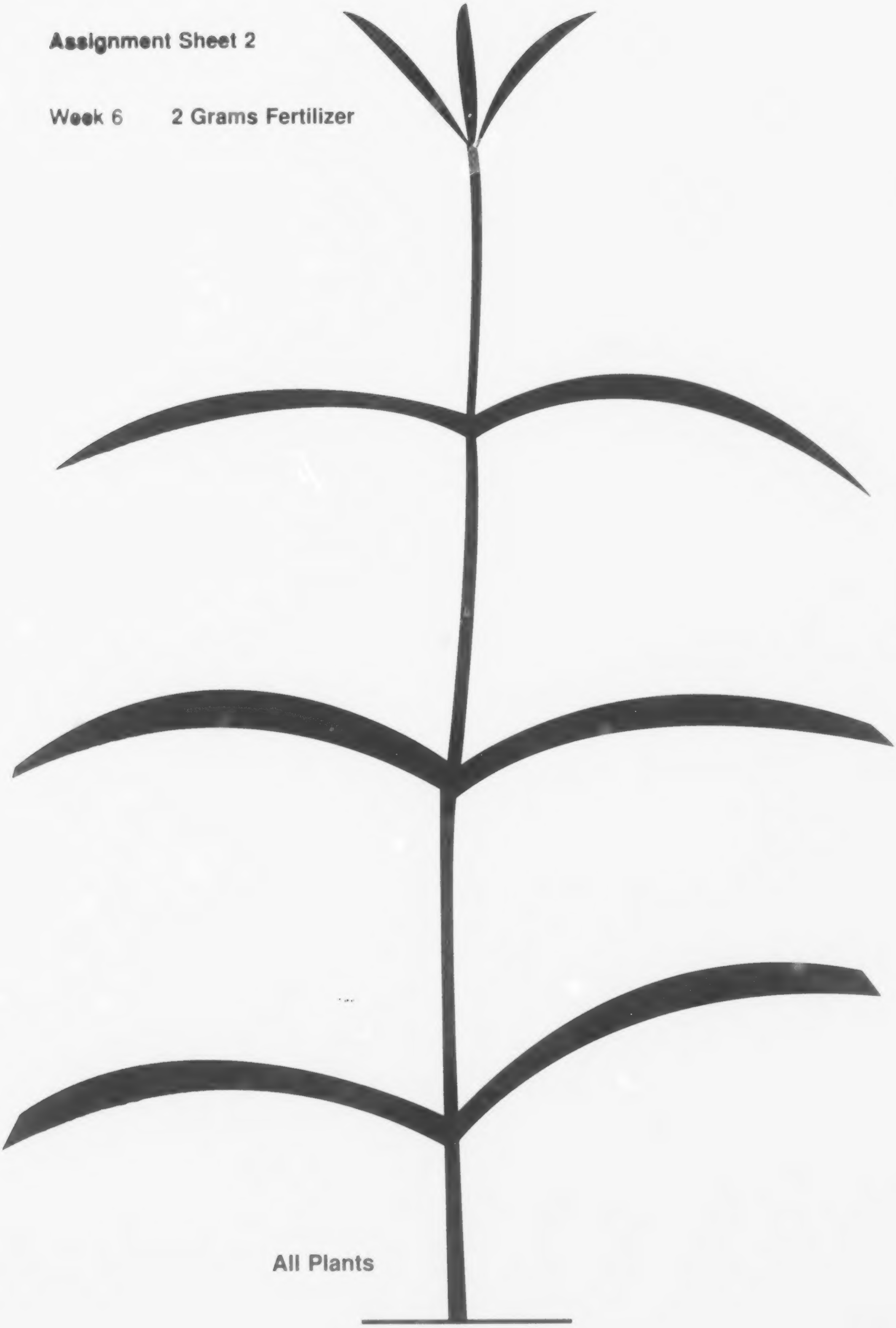
1 Plant **2 Plants Died**

Assignment Sheet 2


Week 6 **No fertilizer**
Week 6 **1 Gram Fertilizer**
All Plants
All Plants

Assignment Sheet 2

Week 6 2 Grams Fertilizer



All Plants

Assignment Sheet 2

Week 6 **4 Grams Fertilizer**

All Plants Died

C. Make a record of any observations about the plants at all stages of growth.

D. Make conclusions about the experiment and determine if they support your hypothesis. Attempt to explain any unexpected results as well.

Introduction to Biotechnology
Unit 1

Assignment Sheet 3—Write a Laboratory Report

Name ______________________________ Overall Rating __________

Evaluation criteria	**Rating**
Heading complete	
Purpose of experiment stated	
Problem to be solved stated	
Hypothesis given	
Materials list complete	
Procedure given	
Results organized and readable	
Conclusions logical	
Report is legible	

Introduction: The purpose of this assignment is to use laboratory information for preparation of a report. This process will be used throughout this course and is patterned after actual reports used in work situations.

Directions: Write a complete laboratory report on the nitrogen fertilizer experiment that was outlined in Assignment Sheet 2. Take all information from your laboratory notebook. Use a laboratory report sheet provided by your instructor or use a separate sheet of paper. Include the following:

A. Heading

B. Introduction

  1. Background

  2. Problem to be solved

  3. Hypothesis

C. Experimental design

  1. Materials used

  2. Procedure

D. Results and analysis of results

E. Conclusions

Introduction to Biotechnology
Unit 1

Laboratory Sheet 1—Determine the Effect of Hand Washing on Microorganisms

Name ______________________________ Overall Rating __________

Evaluation criteria	Rating
Notes kept in laboratory notebook	______
Laboratory report completed	______
Problem clearly defined	______
Hypothesis is reasonable	______
All materials used are listed	______
Procedure followed accurately	______
Analysis of results is understandable	______
Conclusion is logical	______

Introduction: The purpose of this activity is to conduct and record an experimental procedure from start to finish. This procedure demonstrates the presence of microorganism populations and the changes in those populations by hand washing. This is significant for maintaining "clean" conditions for future laboratory activities and many work situations.

Directions: Follow the procedure given below. Keep a record in your laboratory notebook as you do the experiment. Write and hand in a laboratory report when you have completed the experiment.

A. The purpose of this experiment is to determine how effective hand washing is in removing microorganisms from your hands.

B. Write a hypothesis for this experiment.

C. Materials

- 4 sterile petri dishes with nutrient agar
- marker pen
- 3 sterile swabs
- 1 dish pan
- liquid hand soap
- tap water

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Laboratory Sheet 1

- hand scrub brush
- bacterial incubator (maintain 37 degrees centigrade) (Optional — See note on step 9.)

D. Procedure

☐ 1. Use a marker pen to label the bases of the four petri dishes. Do not remove the lids from the dishes.

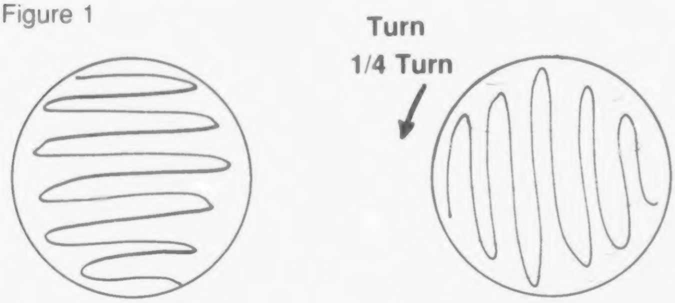
Dish		**Label**
#1	—	Control Your name and date
#2	—	Unwashed Your name and date
#3	—	Washed Your name and date
#4	—	Scrubbed Your name and date

☐ 2. Place dish #1 in the incubator without any treatment.

☐ 3. Use a sterile culture swab to collect material from the surface of your hands. Swab the palms, fingers, around the nails, under the nails, and between the fingers. Do not let the cotton end of the swab touch anything but your hands.

☐ 4. Plate the swab from step 3 onto the nutrient agar in dish #2. Follow the pattern shown below

Figure 1



Laboratory Sheet 1

☐ 5. Wash your hands with soap and water as you normally do. Dry your hands with a towel.

☐ 6. Swab your hand and plate onto the nutrient agar in dish #3. (Follow the procedure in steps 3 and 4.)

☐ 7. Scrub your hands for several minutes using the scrub brush and hand soap. Rinse them with tap water and allow them to air dry.

☐ 8. Swab and streak onto the nutrient agar in dish #4. Follow the procedures in steps 3 and 4.

☐ 9. Place all your petri dishes in the incubator and set it for 37 degrees centigrade (body temperature). Incubate for 48 to 72 hours.

Note: Cultures can be incubated at room temperature as well. Expect slower growth rate and longer time for colony development.

☐ 10. Evaluate bacterial growth by doing colony counts. Use the following rating scale.

Colonies	Contamination level
0	none
1-10	slight
11-20	moderate
21-50	heavy
agar covered	massive

☐ 11. Record all information and observations in your laboratory notebook.

☐ 12. Analyze your results, make your conclusions, and write a laboratory report. Hand in to your instructor.

Genetics and Genetic Engineering
Unit 2

Objective Sheet

Unit Objective

After completing this unit, the student should be able to explain how genetic information is transferred and changed by engineering. The student should be able to demonstrate these competencies by completing the assignment and laboratory sheets and by scoring a minimum of 85 percent on the written test.

Specific Objectives

After completing this unit, the student should be able to:

1. Match terms related to genetics and genetic engineering with the correct definitions.
2. Arrange in order living material from largest to smallest.
3. Match basic cell structures with the correct descriptions.
4. Distinguish between the types of cell reproduction.
5. Complete statements concerning the structures of genetic material.
6. Distinguish between the basic stages involved in the transfer of genetic information.
7. Complete statements about genetic engineering.
8. Arrange in order the steps in the process of genetic engineering.
9. Select true statements concerning vector systems for gene transfer.
10. Describe other methods for gene transfer.
11. Explain the process of sorting DNA by gel electrophoresis.
12. Make a model of a DNA molecule. (Assignment Sheet 1)
13. Genetically engineer a model DNA molecule. (Assignment Sheet 2)
14. Extract DNA from cells. (Laboratory Sheet 1)
15. Transform bacterial cells. (Laboratory Sheet 2)

Genetics and Genetic Engineering
Unit 2

Suggested Activities

Instructional Plan

1. Read the unit carefully and plan for instruction. Study the specific objectives and develop your presentation.

2. Review teaching suggestions and plan classroom and laboratory activities.

3. Plan presentation for enrichment of exceptional students as well as accommodation of special needs students.

4. Make transparencies from the transparency masters included with this unit. These appear in the teacher guide only and are designed to be used with the following objectives:

   TM 1 and Overlay A—RNA Complementary to DNA (Objective 5)
   TM 2—DNA Replication (Objective 6)
   TM 3—Transcription and Translation (Objective 6)
   TM 4—Genetic Engineering (Objective 7)

5. Obtain videotapes, pamphlets, software, and other material to supplement instruction of this unit. See ordering information in the Suggested Supplemental Resources section.

6. Gather materials needed to complete the assignment sheets. See the materials lists in the assignment sheets.

7. Order laboratory equipment and materials needed to complete the laboratory sheets. Order these 2 to 3 weeks in advance of need. Both labs should be trial run by the instructor prior to doing them with the students. Laboratory Sheet 2 requires heating and pouring of media before the student activity begins. Recommended kits for Laboratory Sheets 1 and 2 are available from:

   Carolina Biological Supply Company
   2700 York Road
   Burlington, NC 27215
   800-334-5551

   or

   Box 187
   Gladstone, OR 97027
   800-547-1733

   Alternate kits and supplies are available from:

   Modern Biology, Inc.
   P.O. Box 97
   Dayton, IN 47941-0097
   800-733-6544

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Suggested Activities

8. Review instructions for evaluating student performance and make copies of unit evaluation form.

9. Provide students with unit of instruction. Review objectives with them. Inform them about materials included in the unit test.

10. Discuss assignment sheets and laboratory sheets. Review criteria for evaluation of these activities.

11. Discuss use of the unit evaluation form with students. Select and discuss the rating scale that will be used for the student evaluation.

12. Give written test.

13. Complete assignment sheet ratings, laboratory sheet ratings, and written test scores on the unit evaluation form. Include any additional assignments.

14. Reteach and retest as required.

Teaching Suggestions

Note: Skill areas appearing in bold face type in the teaching suggestions refer to the academic and workplace skills identified by the American Society for Training and Development (ASTD) and the U.S. Department of Labor and adapted by MAVCC.

1. Have a scientist discuss with the class his or her recent work in genetic engineering. Have the speaker discuss the specific techniques used such as microinjection, protoplast fusion, microprojectile bombardment with a particle gun, etc. Slides of the actual work would be helpful. Presentations such as these can reinforce the students' understanding of biotechnology, (**foundation skills--science**), improve their **listening skills**, and increase their **motivation** to learn more about biotechnology.

2. Take a field trip to a biotechnology industry or research facility that uses genetic engineering. Both the procedures being done and the equipment being used should be explained. This is a good chance to see expensive equipment in operation that is unavailable in your laboratory.

    a. You may want to videotape the tour to use with later classes, students who may have missed the trip, or for recruitment of students into your program.

    b. After returning to the classroom, ask students questions about the tour (oral discussion) or have them summarize the main points of the tour in writing.

    c The tour reinforces **group effectiveness skills** and the follow-up discussion and review reinforces **foundation skills (writing)** and **communication skills**.

Suggested Activities

3. Have students write a proposal of how they would like to change an organism by genetic engineering and explain how they would go about making the change. Activities like this help reinforce **creative thinking, problem solving, foundation skills (science)**, and **personal and career development**.

4. If time and money are available, DNA analysis experiments using gel electrophoresis are very worthwhile. One supplier of electrophoresis workstations is:

   Fotodyne Incorporated
   Educational Products Division
   16700 West Victor Road
   New Berlin, WI 53151-4131
   800-362-3686 (800-DNA-FOTO)

   Note: Laboratory exercises for teaching biotechnology to high school students are also available from Fotodyne, Educational Products Division.

5. Encourage students to develop projects for science fairs and to apply for Agriscience Student of the Year Awards through the FFA. These projects encourage **creative thinking** and **problem solving** and help reinforce **foundation skills (science)**. Awards increase **self-esteem** and **motivation** for advanced education.

6. Set up a computer system or make arrangements with your school computer lab for students to use software that reinforces principles of genetic engineering. See the Suggested Supplemental Resources section for more information.

7. Additional suggestions for assignment sheets:

   a. The support stand for Part A of Assignment Sheet 1 can be built ahead of time to save class time.

   b. You may want to copy the tabs in Assignment Sheet 2 using colored paper. This will make the "engineered" portion of their DNA strand more obvious.

   c. Prepare "Model Genetic Engineer" certificates for students who successfully complete Assignment Sheet 2. Certificates reinforce **self-esteem**.

   d. Colored plastic DNA kits available from science education suppliers can be used in addition to or instead of Assignment Sheets 1 and 2. See the Suggested Supplemental Resources section for more information.

Suggested Activities

Resources Used in Developing This Unit

1. Becker, Jeffrey M., Guy A. Caldwell and Eve Ann Zachgo. *Biotechnology, A Laboratory Course.* San Diego: Academic Press, Inc., 1990.

2. *Genetic Engineering of Plants.* National Research Council. Washington, D.C.: National Academy Press, 1984.

3. Kieffer, George H. *Biotechnology, Genetic Engineering, and Society.* University of Illinois at Urbana-Champaign, IL: National Association of Biology Teachers, 1987.

4. Micklos, David and Greg Freyer: *DNA Science: A First Course in Recombinant DNA Technology.* Cold Spring Harbor, NY: Carolina Biological Supply, 1988.

5. *Genetic Engineering in Food and Agriculture.* Ames, IA: Council for Agricultural Science and Technology (CAST), September 1986.

6. *Of the Earth: Agriculture and the New Biology.* St. Louis: Monsanto Company, 1987.

7. Olson, Steve: *Biotechnology: An Industry Comes of Age.* Washington, D.C.: National Academy Press, 1986.

8. Watson, James D., John Tooze and David T. Kurtz. *Recombinant DNA: A Short Course.* New York: W.H. Freeman and Company, 1983.

Suggested Supplemental Resources

1. *Biotechnology, Genetic Engineering, and Society.*

   National Association of Biology Teachers
   11250 Roger Bacon Drive #19
   Reston, VA 22090

2. Filmstrip and cassette tape—*Changing Genetic Messages.* Available from:

   National Geographic Society
   Educational Services, Dept. 5295
   Washington, DC 20036
   800-368-2728

Suggested Activities

3. Videotapes

   a. *Electrophoresis — Theory and Practice*. VHS, 25 minutes.

   b. *An Introduction to Molecular Genetics*. VHS, 50 minutes.

   a and b are available from:

   Modern Biology, Inc.
   P.O. Box 97
   Dayton, IN 47941-0097
   800-733-6544

   c. *The Building Blocks of Life*. 61 minutes. (VID 4023). Available from:

   Queue, Inc.
   338 Commerce Drive
   Fairfield, CT 06430
   800-232-2224

4. DNA models and kits and *DNA Made Easy*. Help to reinforce DNA structure. Available from many science education suppliers such as:

   Fisher Scientific
   Educational Materials Division
   4901 West LeMoyne Street
   Chicago, IL 60651
   800-621-4769

   or

   Carolina Biological Supply Company
   2700 York Road
   Burlington, NC 27215
   800-334-5551

   or

   Box 187
   Gladstone, OR 97027
   800-547-1733

   Teacher's Guide for *DNA Made Easy* is available from:

   National Teaching Aids, Inc.
   1845 Highland Avenue
   New Hyde Park, NY 11040

Suggested Activities

5. Computer software

   a. *Genetic Engineer's Toolbox* (HRM 527A) for Apple II's

   b. *Gene Machine* (HRM 537A) for Apple II's

   c. *Protein Synthesis Codon* by COM Press for Apple II's, IBM PC, IBM PC 3.5, and PC-jr.

   a-c are available from:

   Queue, Inc.
   338 Commerce Drive
   Fairfield, CT 06430
   800-232-2224

   d. *A Tutorial in Recombinant DNA Technology*, developed by Cornell University. Minimum memory: 1Mb, suggested system: Version 4.2 or later, hard disk recommended, other requirements: Hyper Card 1.2. Available from:

   Intellimation Library for the Macintosh
   Department YAHJ
   130 Cremona Drive, P.O. Box 1922
   Santa Barbara, CA 93116-1922
   800-3-INTELL

   e. *Plant and Animal Cells* for Apple 48K.

   f. *DNA — The Master Molecule* for Apple 48K or IBM 64K.

   g. *Gene Machine* for Apple 48K, TRS-80 48K, or C64.

   h. *Gene Structure and Function*. Innovative Educational Software. For Apple 48K.

   e-h are available from:

   Projected Learning Programs, Inc.
   P.O. Box 3008
   Paradise, CA 95967-3008
   800-248-0757

Suggested Activities

6. *Secondary Biotechnology Unit* — Consists of nineteen lessons including experiments and hands-on activities for high school students. Sponsored by the Monsanto Fund and the National Science Foundation. Developed by:

   Mathematics and Science Education Center
   8001 Natural Bridge
   St. Louis, MO 63121
   314-553-5650

7. Workshop assistance—Most biotechnology/science supply companies also offer assistance on how to set up a biotechnology laboratory. One such company is:

   EDVOTEK, Inc.
   P.O. Box 1232
   West Bethesda, MD 20827-1232
   800-EDVOTEK

Instructions For Evaluating Student Performance

Assignment Sheets — Be sure the student understands the criteria on which the evaluation is based. Assign a point value to each criterion and convert the total points to a percentage for grading.

Laboratory Sheets — Rate both process and product. The process should be based on the evaluation criteria for the laboratory activity. Observe the student during the laboratory activity and complete the rating by assigning a point value to each criterion and converting the point total to a percentage for grading. The laboratory product should be based on the completed laboratory report.

Performance evaluation can be based on the combined process and product evaluation. A suggested performance evaluation key is given below:

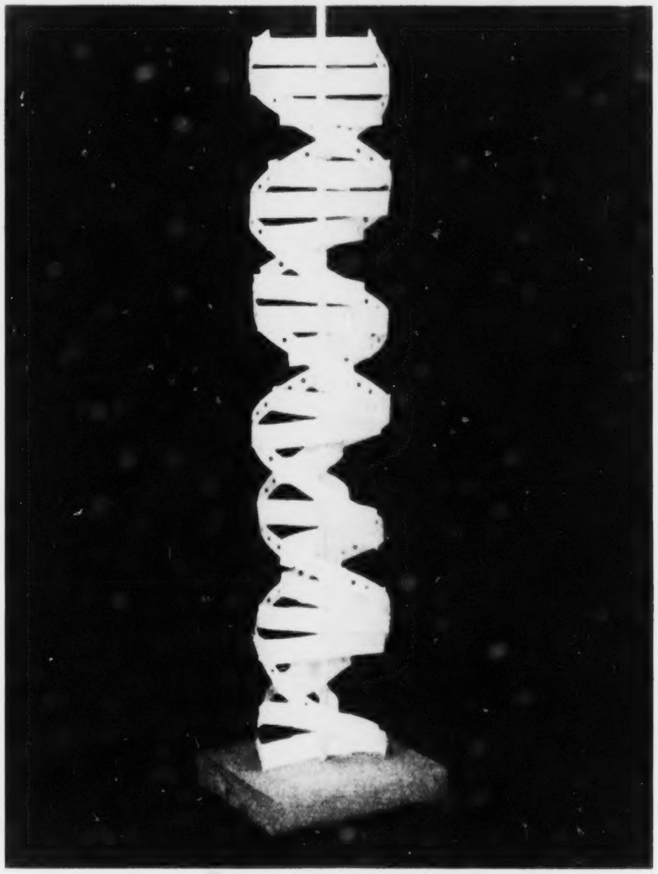
Performance level	Evaluation
90-100%	Skilled — Able to perform laboratory activity and arrive at a sound conclusion with no additional practice
80-90%	Moderately Skilled — Able to perform most laboratory activities and arrive at reasonable conclusions
70-80%	Limited Skill — Can perform some laboratory activities and work toward conclusions but needs additional practice in some areas
0-70%	Unskilled — Not able to follow procedure and reach a satisfactory conclusion; performance and evaluation must be repeated

Genetics and Genetic Engineering
Unit 2

Answers to Assignment Sheets

Answers to Assignment Sheet 1

The quality and clarity of the model constructed is the key evaluation tool. The photograph of a completed model can serve as a guide.



Answers to Assignment Sheet 2

The clarity and precision of the altered segment on the DNA model is the basis for evaluation.

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Genetics and Genetic Engineering
Unit 2

Answers to Laboratory Sheets

Answers to Laboratory Sheet 1

The successful extraction of DNA and submission of the completed lab notebook and report is the basis for evaluation. An answer sheet for the questions is provided with the kit materials.

Answers to Laboratory Sheet 2

Successful transformation of bacteria from ampicillin-susceptible to ampicillin-resistant is the basis for evaluation. Proper recording of activities in the lab notebook and a completed lab report are other evaluation tools.

Answers to study questions (Carolina Biological kit)

1. a. Non-transformed *E. coli* on luria broth agar with no ampicillin should grow because no antibiotic is present to inhibit their growth.

   b. Transformed *E. coli* on luria broth agar with no ampicillin should grow because no antibiotic is present and transformed bacteria should be viable.

   c. Non-transformed *E. coli* on luria broth agar with ampicillin should show no growth because they are susceptible to antibiotic action.

   d. Transformed *E. coli* on luria broth agar with ampicillin should show growth because they have acquired the gene for resistance to the antibiotic. Not all cells acquire the resistance gene; therefore, a small population of cells will not grow.

2. +pAMP cells are able to grow in the presence of ampicillin because they have acquired the gene for ampicillin resistance through genetic engineering. –pAMP cells will not grow on agar containing ampicillin because they do not have the gene for resistance.

3. Factors that influence transformation:

   a. Viability of the bacterial culture
   b. Purity and amount of plasmid DNA
   c. Laboratory conditions such as chemicals used and concentration, temperature conditions, and time intervals.
   d. Incubation conditions
   e. Aseptic technique

Genetics and Genetic Engineering
Unit 2

Answers to Written Test

1.

a.	9	e.	16	i.	11	m.	24
b.	6	f.	4	j.	8	n.	25
c.	15	g.	13	k.	17	o.	20
d.	3	h.	1	l.	21		

2. a. 3
   b. 2
   c. 4
   d. 1

3. a. 8
   b. 1
   c. 2
   d. 6
   e. 4

4. b

5. a. Genes
   b. Nucleotides
   c. Helix
   d. Backbone
   e. Thymine
   f. C
   g. Single

6. a. Transcription to RNA
   b. Translation to protein
   c. DNA replication

7. a. Genes
   b. Some
   d. Cut

8.

a.	4	e.	1
b.	5	f.	7
c.	3	g.	2
d.	6		

9. a, b

Answers to Written Test

10. Descriptions should include the following:

    a. Microprojectile bombardment using a particle gun—DNA segments containing genes are bonded to microscopic metal particles. These are loaded into a blank cartridge and fired in a vacuum chamber onto cells to be transformed. Some cells take up the foreign DNA and replicate with their own.

    b. Protoplast fusion—Plant or bacterial cells have their cell walls removed with the cell membrane left intact. With careful laboratory procedure, protoplasts from different plants can be fused and a cybrid plant developed.

    c. Microinjection—Foreign DNA is injected directly into cell nucleus using a microscopic pipette and other specialized laboratory equipment.

    d. Electroporation—Electrical field causes pores to form in cells. Foreign DNA enters cells through pores. Pores close when electrical pulse stops.

11. Description should include the following:

    Uses electricity and gelatin-like material to sort DNA molecules into distinct bands. The sorting process occurs because smaller molecules move more rapidly and larger more slowly. Eventually they sort into bands composed of different-sized molecules.

Genetics and Genetic Engineering
Unit 2

Written Test

Name ________________________________ Score ____________

1. Match the terms on the right with the correct definitions.

Note: Terms on this page match the definitions on this page.

______a. Technology involved in removing, modifying, or adding genes to a DNA molecule

______b. To remove a part by a process similar to cutting

______c. A heritable change in genetic makeup

______d. Organisms or cells of nearly identical genetic makeup derived from a single source

______e. Building blocks of nucleic acid composed of a sugar, a phosphate, and a nitrogenous base

______f. Containing structures that match or bond with related structures

______g. Enzyme used to join pieces of DNA

______h. Porous gelatin-like material used as a support matrix for living cells in artificial environments

______i. A cell or organism that harbors another organism or DNA from a foreign source

______j. A series of three nucleotide bases that determine the amino acid order and the proteins formed in cell reproduction

______k. A small (usually circular) piece of DNA that is separate from the chromosomal DNA

1. Agar
2. Centrifuge
3. Clones
4. Complementary
5. Electrophoresis
6. Excise
7. Expression
8. Genetic code
9. Genetic engineering
10. Genetics
11. Host
12. Hybrid
13. Ligase
14. Molecular weight
15. Mutation
16. Nucleotides
17. Plasmid
18. Recombinant DNA
19. Regenerate

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Written Test

______l. Order of nucleotides or amino acids

______m. To change the genetic makeup of an organism by alteration of DNA

______n. An agent such as a plasmid used to transfer DNA into a host cell

______o. Enzyme that cuts DNA strands at specific sites

20. Restriction enzyme
21. Sequence
22. Template
23. Trait
24. Transform
25. Vector

2. Arrange in order the living material listed by placing a 1 by the largest structure, a 2 by the next-larger, a 3 by the next-smaller, and a 4 by the smallest.

______a. Tissue

______b. Organ

______c. Cell

______d. Organism

3. Match the basic cell structures listed on the right with the correct descriptions.

______a. Site where new proteins are produced as a result of genetic expression

______b. Delicate structure that surrounds the cell

______c. Protective layer in plants that keeps the cell intact

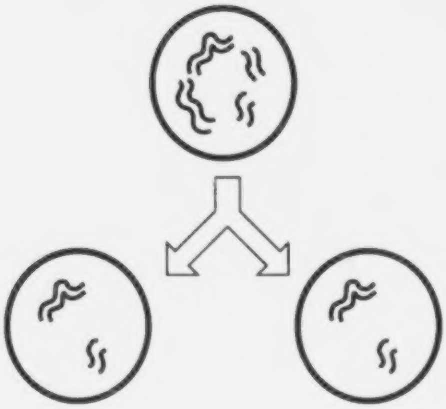
______d. Control center of a cell containing most of the DNA

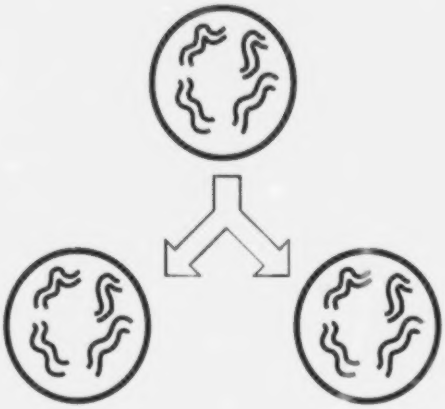
______e. Cell fluid containing all cell structures

1. Cell membrane
2. Cell wall
3. Chromosomes
4. Cytoplasm
5. Mitochondria
6. Nucleus
7. Plasmid
8. Ribosome

Written Test

4. Distinguish between the types of cell reproduction by placing an "X" next to the illustration of mitosis.





a. ______________________ b. ______________________

5. Complete the following statements concerning the structures of genetic material by circling the correct answers.

   a. Chromosomes are the physical carriers of (cells, genes).

   b. DNA is composed of two complementary chains of (amino acids, nucleotides).

   c. The overall configuration of DNA shows the chains coiled into a double (helix, parabola).

   d. The sugar and phosphate make up the (backbone, complementary pairs).

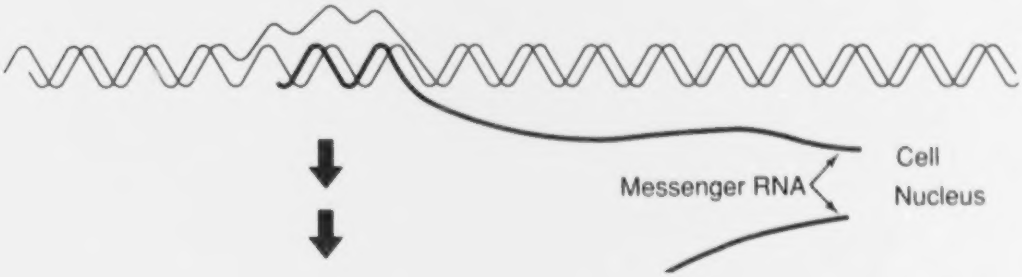
   e. The nitrogenous bases used in structuring DNA are adenine, guanine, cytosine, and (thymine, uracil).

   f. G (guanine) always pairs with (A, T, C, U).

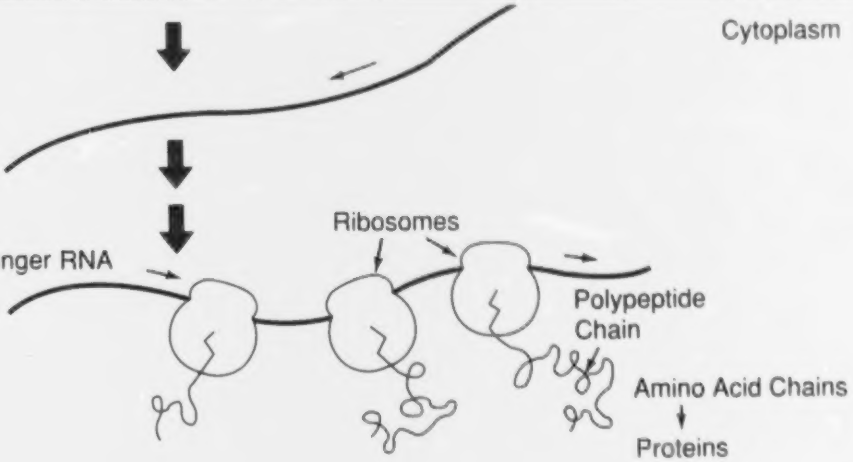
   g. RNA is usually (single-, double-) stranded.

Written Test

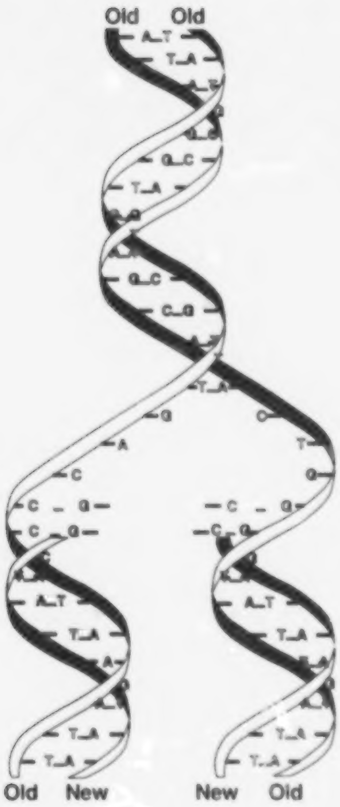
6. Distinguish between the basic stages involved in the transfer of genetic information by labeling the following illustrations as DNA replication, transcription to RNA, or translation to protein.


Messenger RNA
Cell
Nucleus

a. ____


Cytoplasm
Ribosomes
Messenger RNA
Polypeptide
Chain
Amino Acid Chains
Proteins

b. ____


Old
Old
A T
T A
G C
T A
G C
C G
T A
G
A
C
C G
C G
C
T
G
C G
C G
A T
T A
T A
T A
Old
New
New
Old

c. ____

7. Complete the following statements about genetic engineering by circling the correct answers.

   a. Genetic engineering is moving (chromosomes, genes) from one organism to another.

   b. Plasmids are found in (some, all) organisms.

   c. Restriction enzymes are used to (cut, close) DNA at specific sites.

Written Test

8. Arrange in order the steps in the process of genetic engineering by placing the appropriate numbers (1-7) in the appropriate blanks.

   ______a. Transfer the plasmid DNA into the cell by transformation.

   ______b. Replicate the plasmid inside a bacterial cell.

   ______c. Transfer the piece of excised DNA to a vector.

   ______d. Observe for genetic expression.

   ______e. Locate the desired gene.

   ______f. Cultivate the transformed organisms so a new product or process can be used.

   ______g. Isolate and remove the desired gene from all others in the nucleus.

9. Select true statements concerning vector systems for gene transfer by placing an "X" next to the true statements.

   ______a. Vectors are DNA-containing materials that carry foreign DNA into a host cell and replicate there.

   ______b. Vectors are an effective and simple way of transferring DNA.

   ______c. Vectors work in all plant and animal cells.

10. Write a brief description of the following methods for gene transfer.

    a. Microprojectile bombardment using a particle gun— ______________________

    ____

    ____

    ____

    ____

b. Protoplast fusion— ____________________

____

____

____

c. Microinjection— ____________________

____

____

____

d. Electroporation— ____________________

____

____

____

11. Describe the sorting of DNA by gel electrophoresis.

____

____

____

____

____

Genetics and Genetic Engineering
Unit 2

Unit Evaluation Form

Student Name ______________________________ Unit Rating __________

Assignment Sheet 1—Make a model of a DNA molecule Rating ______

Comments: ____

____

Assignment Sheet 2—Genetically engineer a model DNA molecule Rating ______

Comments: ____

____

Laboratory Sheet 1—Extract DNA from cells Rating ______

Comments: ____

____

Laboratory Sheet 2—Transform bacterial cells Rating ______

Comments: ____

____

Written Test Scores

Pretest ______ Posttest ______ Other ______

Other ____

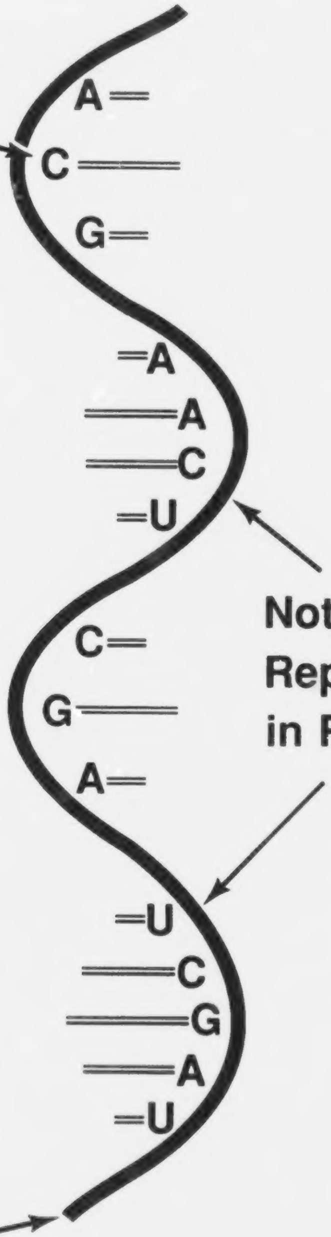
____

Teacher Signature ______________________________ Date __________

Student Signature ______________________________ Date __________

***Permission to duplicate this form is granted.**

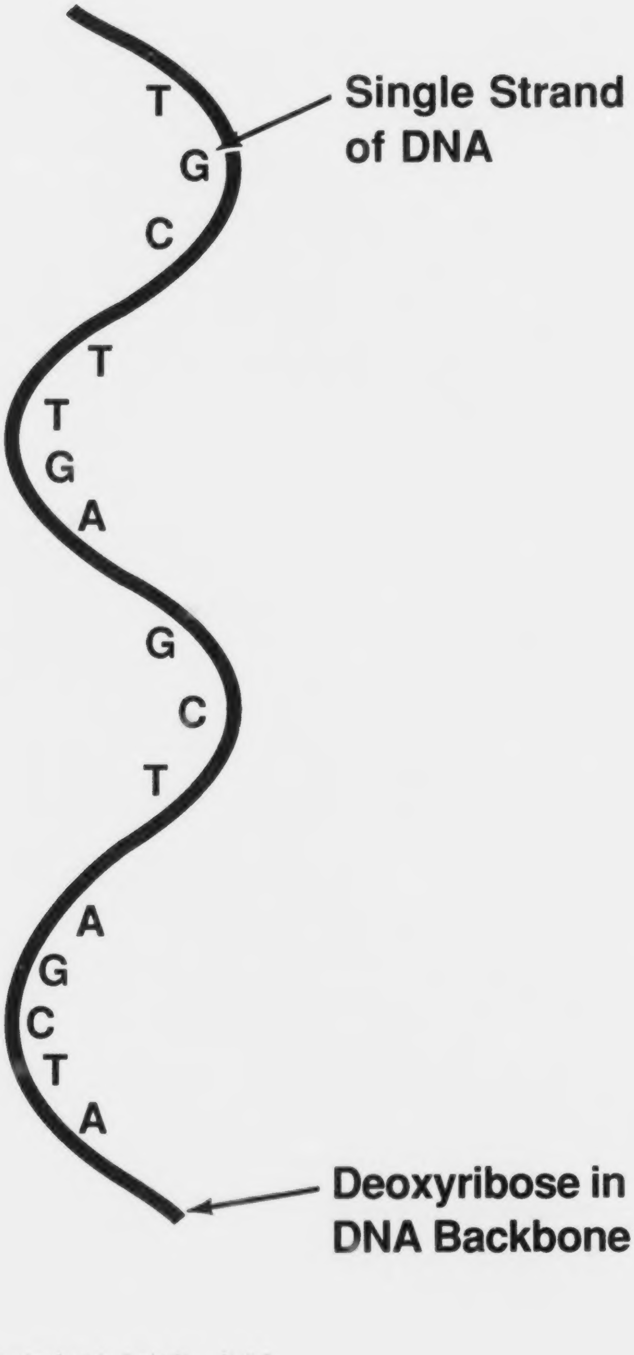
RNA Complementary to DNA



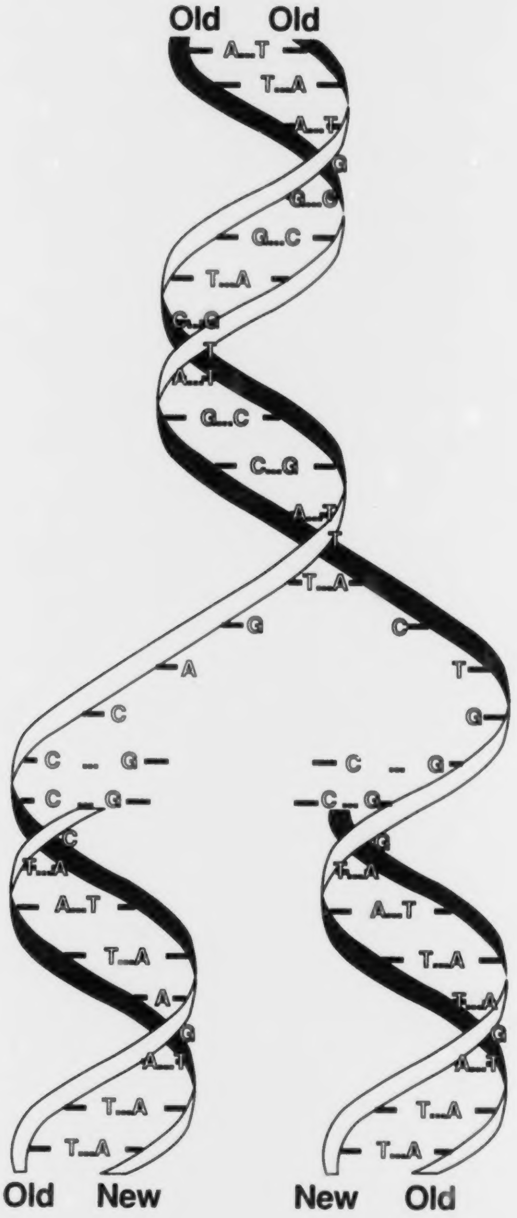
Complementary RNA

Note: Uracil Replaces Thymine in RNA.

Ribose in RNA Backbone

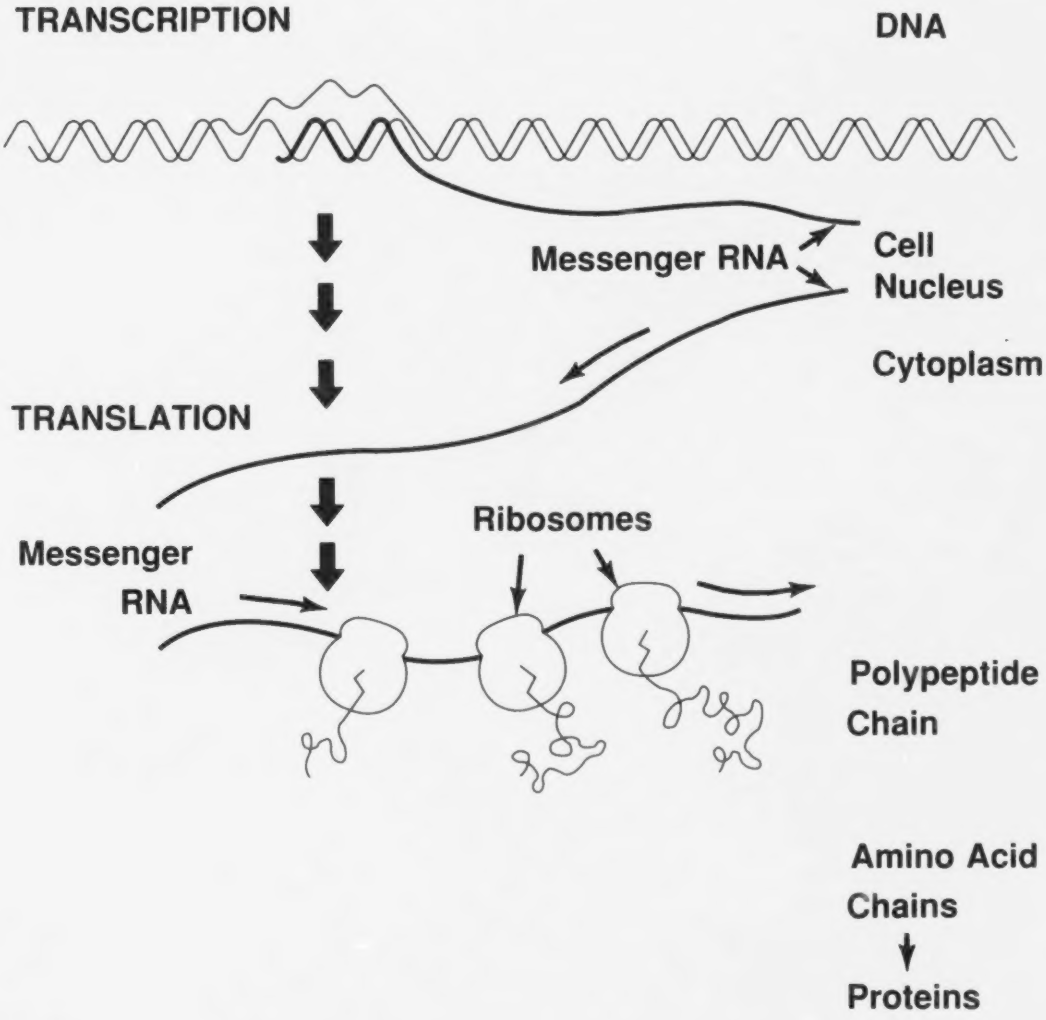

T
G
C
T
T
G
A
G
C
T
A
G
C
T
A
Single Strand of DNA
Deoxyribose in DNA Backbone

DNA Replication


Old
Old
Old
New
New
Old

Source: U.S. Government Printing Office

Transcription and Translation


TRANSCRIPTION
DNA
Messenger RNA
Cell
Nucleus
Cytoplasm
TRANSLATION
Ribosomes
Messenger
RNA
Polypeptide
Chain
Amino Acid
Chains
Proteins

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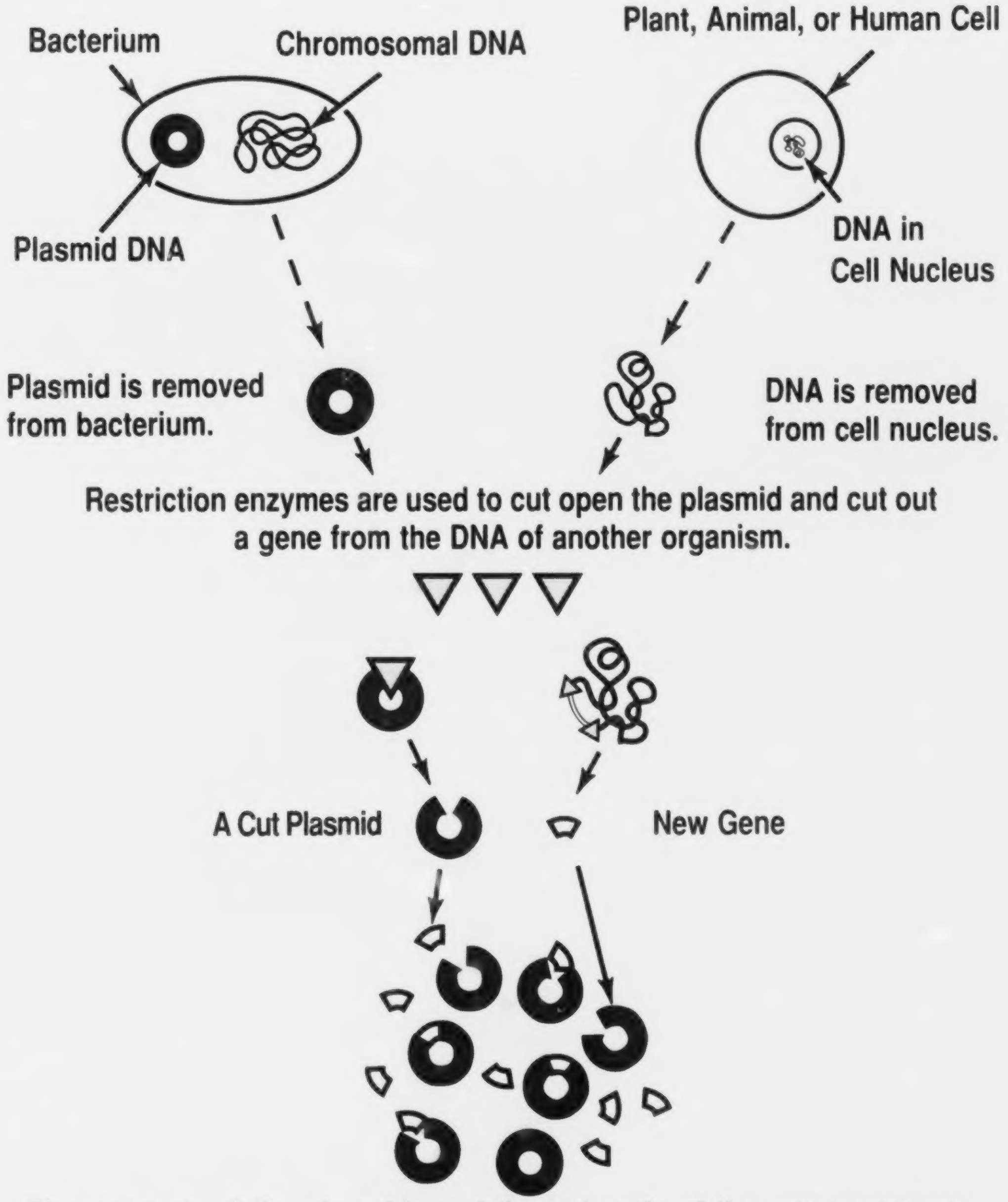
Genetic Engineering


Bacterium
Chromosomal DNA
Plant, Animal, or Human Cell
Plasmid DNA
DNA in
Cell Nucleus
Plasmid is removed
from bacterium.
DNA is removed
from cell nucleus.
A Cut Plasmid
New Gene

Restriction enzymes are used to cut open the plasmid and cut out a gene from the DNA of another organism.

The cut ends of the plasmids and the cut ends of the new genes are chemically "sticky" so they will attach to each other—recombine—to form a new loop containing the inserted gene. This technique is called "gene splicing" or recombinant DNA technology.

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Genetics and Genetics Engineering
Unit 2

Information Sheet

1. **Terms and definitions**

   a. **Agar** — Porous gelatin-like material used as a support matrix for living cells in artificial environments

   b. **Centrifuge** — Device for separating substances on the basis of density

   c. **Clones** — Organisms or cells of nearly identical genetic makeup derived from a single source

   d. **Complementary** — Containing structures that match or bond with related structures

   e. **Electrophoresis** — Technique used to separate migrating molecules in an electrical field

   f. **Excise** — To remove a part by a process similar to cutting

   g. **Expression**—The appearance of a trait directed by a gene

   h. **Genetic code** — A series of three nucleotide bases that determine the amino acid order and the proteins formed in cell reproduction

   i. **Genetic engineering** — Technology involved in removing, modifying, or adding genes to a DNA molecule

   j. **Genetics** — Science dealing with passage of traits from one generation to another

   k. **Host** — A cell or organism that harbors another organism or DNA from a foreign source

   l. **Hybrid** — Offspring or cell originating from parents with differing genetic makeup

   m. **Ligase** — Enzyme used to join pieces of DNA

   n. **Molecular weight** — Sum of the atomic weights of all the atoms in a molecule

   o. **Mutation** — A heritable change in genetic makeup

   p. **Nucleotides** — Building blocks of nucleic acid composed of a sugar, a phosphate, and a nitrogenous base

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Information Sheet

q. **Plasmid** — A small (usually circular) piece of DNA that is separate from the chromosomal DNA

r. **Polymerase** — An enzyme that joins nucleotides to make nucleic acids

s. **Recombinant DNA** — DNA that has been altered by genetic engineering

t. **Regenerate** — To return an altered organism to its original state

u. **Restriction enzyme (restriction endonuclease)** — Enzyme that cuts DNA strands at specific sites

v. **Sequence** — Order of nucleotides or amino acids

w. **Template** — A pattern used for developing a complementary structure

x. **Trait** — A characteristic resulting from gene expression

y. **Transform** — To change the genetic makeup of an organism by alteration of DNA

z. **Vector** — An agent such as a plasmid used to transfer DNA into a host cell

2. **Organization of living material** (listed in order from largest to smallest)

a. **Organism** — A unit of living matter capable of independent function and reproduction

- Complex organism (higher organism) —An organism with cells, tissues, and organs arranged to function as a single unit.

  Examples: Plants, animals, humans

- Simple organism—A single-celled organism

  Examples: Bacteria, amoebae

b. **Organ** — Arrangement of tissues which provides life-support function for an organism

Examples: A leaf is a plant organ that carries out respiration, transpiration, and photosynthesis. A kidney is an animal organ that removes wastes from the bloodstream.

Information Sheet

c. **Tissue** — Arrangement of cells with similar structures in clusters or sheets for specific function in an organ

Examples: Epithelium is a sheet of cells that forms the lining of an organ. Parenchyma is a cluster of cells that stores energy compounds or carries on photosynthesis in plants.

d. **Cell** — Smallest structural unit of living matter that is capable of carrying out basic life processes

- Eukaryotic cell has a well defined nucleus.
- Prokaryotic cell is without a well defined nucleus.

3. Basic cell structures

a. Cell wall—Protective layer in plants that keeps the cell intact

b. Cell membrane—Delicate structure that surrounds the cell

c. Chloroplasts—Site of photosynthesis in plant cells; also contain some DNA

d. Cytoplasm—Cell fluid containing all cell structures

e. Nucleus (pl. nuclei)—Control center of a cell containing most of the DNA

f. Chromosomes—Structures that are physical carriers of genes, are made up of DNA, and are located in the cell nucleus

g. Mitochondria—Energy-producing structures in the cell cytoplasm that contain some DNA

h. Plasmid—Extra chromosomal piece of DNA located in the cell cytoplasm

i. Ribosome—Site where new proteins are produced as a result of genetic expression

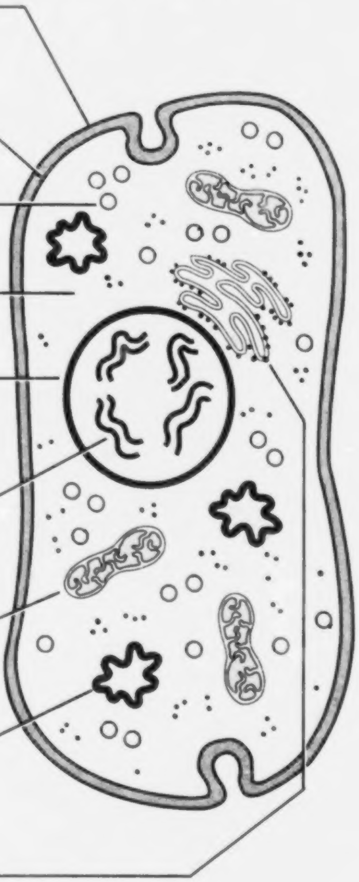


Figure 1—Cell Structures

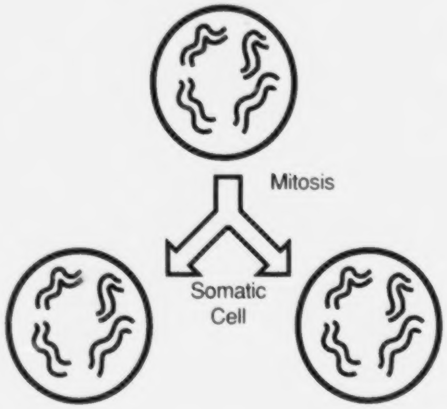
Information Sheet

4. Types of cell reproduction

a. Mitosis

- Occurs in body (somatic) cells
- Increases by simple division (mitosis)
- Chromosomes remain paired during cell division

Figure 2—Mitotic Cell Division

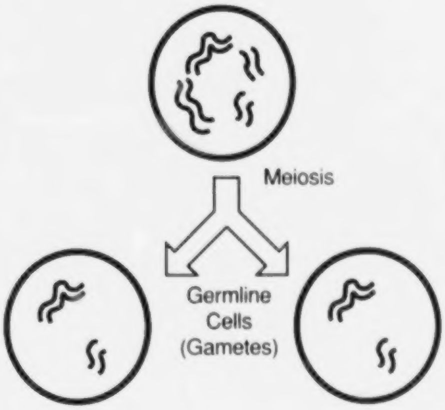


b. Meiosis

- Occurs in reproductive (germline) cells (gametes)
- Increases by division into single chromosomes and recombination of male and female cells to form a new individual
- One chromosome from each parent forms the new pair.

Note: Each organism has a specific number of paired chromosomes.

Figure 3—Meiotic Cell Division



Information Sheet

5. Structures of genetic material

a. **Chromosomes**

- Are the physical carriers of genes
- Are normally paired in cell nuclei
- Each particular organism has a specified set

b. **Genes**

- Are composed of DNA
- Are arranged at specific sites on chromosomes
- Determine the traits that are passed from one generation to another

c. **Deoxyribonucleic acid (DNA)**

- Is composed of two complementary chains of nucleotides
  - — A single nucleotide is composed of a sugar, a phosphate group, and a nitrogenous base.

Base
|
Sugar — Phosphate

- — Nucleotides can then be linked into chains.

Base **Base** **Base**
| | |
Sugar — Phosphate — Sugar — Phoshate — Sugar — Phosphate

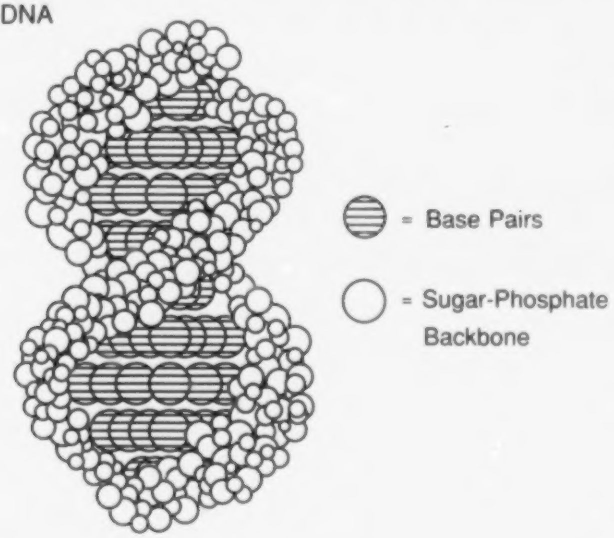
Note: The number of nucleotide units in the chain vary considerably. A DNA molecule from the largest human chromosome is composed of approximately 5.4×10^8 nucleotides!

Information Sheet

- The overall configuration of DNA shows the chains of nucleotides coiled into a double helix.

  Note: Think of this as a "twisted ladder" where you imagine twisting the ends of a flexible ladder. You will make a model of this in Assignment Sheet 1 which should help you visualize the overall form of DNA.

  Figure 4—DNA



  — The sugar (deoxyribose) and phosphate make up the backbone of the helix.

  — The nitrogenous bases form complementary pairs.

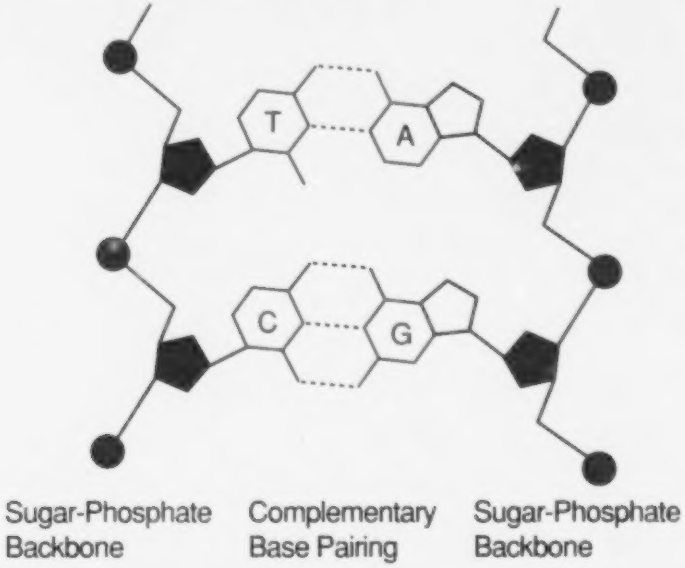
  — The four nitrogenous bases used in structuring DNA are:

    - Adenine (coded A)
    - Guanine (coded G)
    - Thymine (coded T)
    - Cytosine (coded C)

Information Sheet

- Complementary base pairs are:
  - A always pairs with T
  - G always pairs with C

Figure 5—Complementary base pairing


T
A
C
G
Sugar-Phosphate Backbone
Complementary Base Pairing
Sugar-Phosphate Backbone

- Sequences of nucleotides along the DNA strand form the "genetic code" and determine the protein that will be produced.

d. **Ribonucleic acid (RNA)**

- Is usually a single-stranded molecule similar to DNA except that there is a different sugar in the backbone (ribose instead of deoxyribose) and uracil (U) is used in place of thymine for complementing adenine.
- Main function is in transcription and translation.

Information Sheet

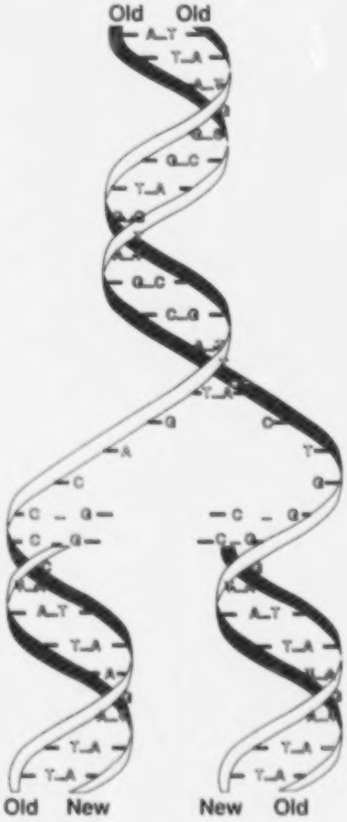
6. Steps in transfer of genetic information

Note: These are simplified steps and show only the basic procedures. Actual transfer procedures are much more complicated.

a. DNA replication (maintenance)

- Method of reproducing a DNA molecule that is exactly like the first (parent) DNA
- Double-stranded DNA unwinds and forms single strands.
- Each strand serves as a template for building a complementary strand to complete a new double-stranded molecule.

Figure 6—DNA replication

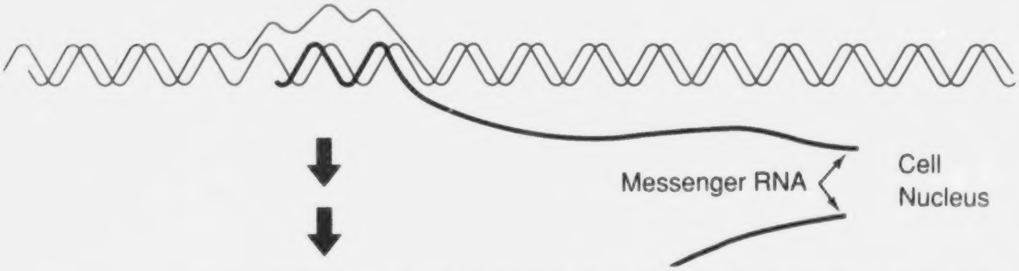

Old
Old
A_T
T_A
G_C
T_A
G_C
C_G
T_A
G
A
C
C G
C G
A_T
T_A
T_A
T_A
C
T
G
C G
C G
A_T
T_A
T_A
T_A
Old
New
New
Old

Information Sheet

b. DNA transcription to RNA

- Means of getting the genetic instructions from DNA transferred to the "factories" (ribosomes) where new proteins are formed.
- Part of the DNA molecule unwinds; then a polymerase reads the DNA nucleotide sequence and forms a complementary messenger RNA (mRNA) strand.

Figure 7—Transcription

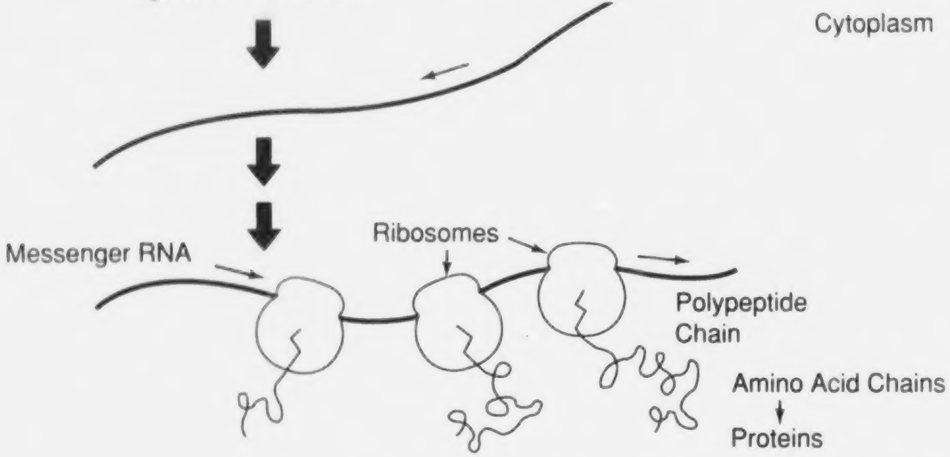

Messenger RNA
Cell
Nucleus

Note: Transcription takes place in the nucleus of eukaryotic cells and the cytoplasm of prokaryotic cells.

c. Translation of RNA genetic code to form new proteins

- Messenger RNA takes instructions from DNA to the ribosomes.
- Ribosomes read the mRNA sequences and incorporate amino acids into long chains that make up proteins.

Figure 8—Translation


Cytoplasm
Messenger RNA
Ribosomes
Polypeptide
Chain
Amino Acid Chains
Proteins

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Information Sheet

7. Genetic engineering

a. Definitions

- Technology involved in removing, modifying, or adding genes to a DNA molecule
- Movement of pieces of genetic information (genes) from one organism to another
- Other terms referring to genetic engineering
    - Recombinant DNA technology
    - Recombinant DNA science
    - Gene transfer
    - Gene splicing
    - Gene cloning

b. Natural genetic engineering

- Alternations in the genetic makeup of plants and animals allow them to respond to changes in their environment.
- Some bacteria and viruses change the function of cells by inserting their DNA into the DNA of the cell.

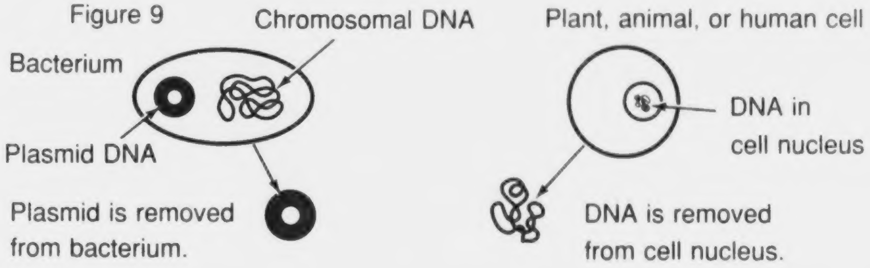
  Example: Crown gall of plants is caused by bacteria that alter the DNA of the plant cells and make them grow at an abnormally rapid rate.
- Natural selection ensures that the adapted individual leaves offspring for the next generation. (result of genetic change and often referred to as "survival of the fittest.")

Information Sheet

c. Scientific genetic engineering

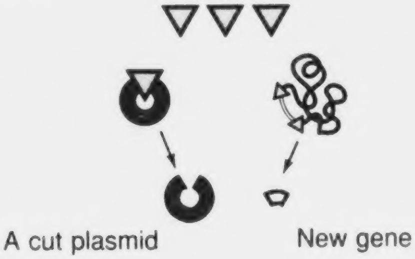
- Scientists have developed the ability to transfer genetic material from one organism to another.
- Plasmids found in some (not all) organisms can be engineered to accept DNA from other sources.

Figure 9


Chromosomal DNA
Plant, animal, or human cell
Bacterium
DNA in cell nucleus
Plasmid DNA
Plasmid is removed from bacterium.
DNA is removed from cell nucleus.

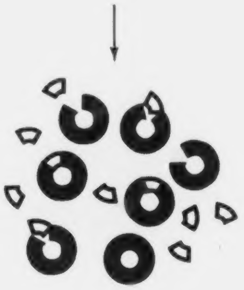
- Restriction enzymes are used to cut the DNA molecule at specific sites.

Figure 10


A cut plasmid
New gene

- Cut ends of plasmid rings can accept pieces of DNA from other organisms.

Figure 11



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- The ability to "cut and splice" DNA segments is providing many opportunities for changing the function of organisms.

Information Sheet

8. Steps in the process of genetic engineering

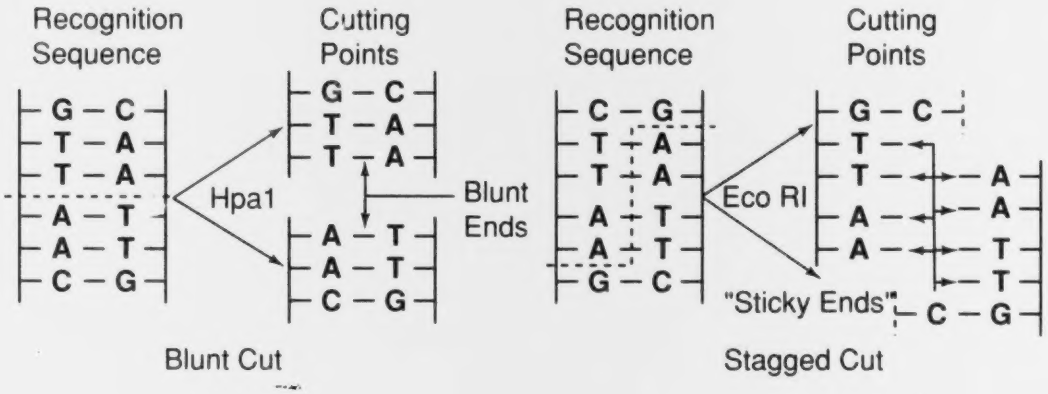
a. Locate the desired gene.

Note: This step is difficult because there are hundreds of thousands of genes in a cell nucleus.

b. Isolate and remove the desired gene from all others in the nucleus.

- Use restriction enzymes.
- These enzymes cut the DNA molecule at a specific site to remove the nucleotide sequence that contains the desired gene.

Figure 12—Recognition sequence and cutting DNA by restriction enzymes Hpa 1 and Eco RI


Recognition Sequence
Cutting Points
Recognition Sequence
Cutting Points
G – C
T – A
T – A
A – T
A – T
C – G
Hpa1
Blunt Ends
C – G
T – A
T – A
A – T
A – T
G – C
Eco RI
"Sticky Ends"
Blunt Cut
Stagged Cut

c. Transfer the piece of excised DNA to a vector (commonly a plasmid in a bacterial cell).

- Use same restriction enzymes to open the plasmid ring.
- Insert DNA pieces excised in step b.
- New gene can attach to the open ends of plasmid.
- Ligase may be needed to close plasmid ring.

d. Transfer the plasmid DNA into the cell by transformation.

Information Sheet

e. Replicate the plasmid inside a bacterial cell.

- This will produce many copies of the plasmid containing the new genetic material (gene cloning).
- New genetic information is included in each new generation of cells.

f. Observe for genetic expression.

- Desired trait must appear in the target organism.
- Genes have "control signals" that must be present for the gene to be expressed and the trait to appear.
- If the new trait appears, the organism is "transformed" — has a new genetic function.

g. Cultivate the transformed organisms so a new product or process can be used.

9. **Vector systems for gene transfer**

a. Vectors are DNA-containing materials that carry foreign DNA into a host cell and replicate these inside the cell.

b. Vectors are presently the simplest and most effective method of transferring DNA.

c. Vectors are not universal in their application.

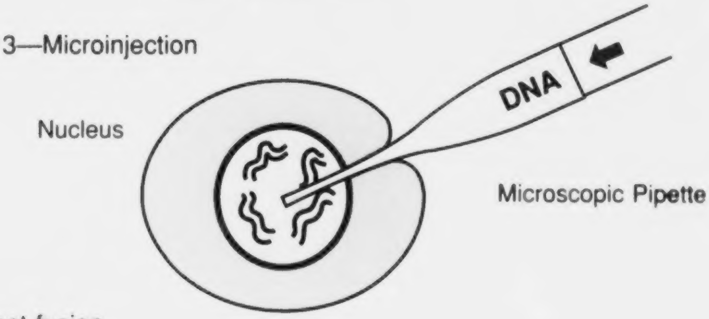
10. **Other methods for recombining DNA**

a. Microinjection

- Involves direct injection of foreign DNA into a cell nucleus
- Requires specialized laboratory equipment
- Requires experience in using equipment
- Can only transform small numbers of cells

Information Sheet

Figure 13—Microinjection

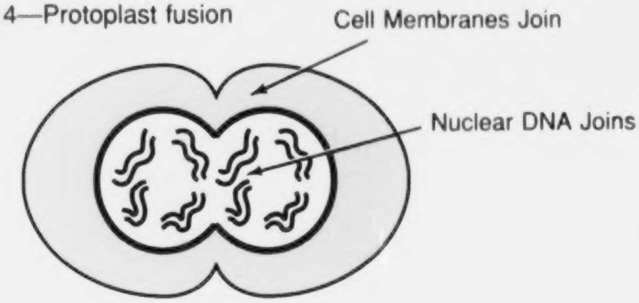


b. Protoplast fusion

- Protoplasts are plant or bacterial cells with the cell wall removed but the cell membrane intact.
- Protoplasts from different plants can be fused together to form new "cybrids" (cytoplasmic hybrids).
- Requires careful laboratory procedures and treatments.
- Works in just a few plant species.

  Examples: Potato, tomato, petunia, tobacco, carrot

Figure 14—Protoplast fusion



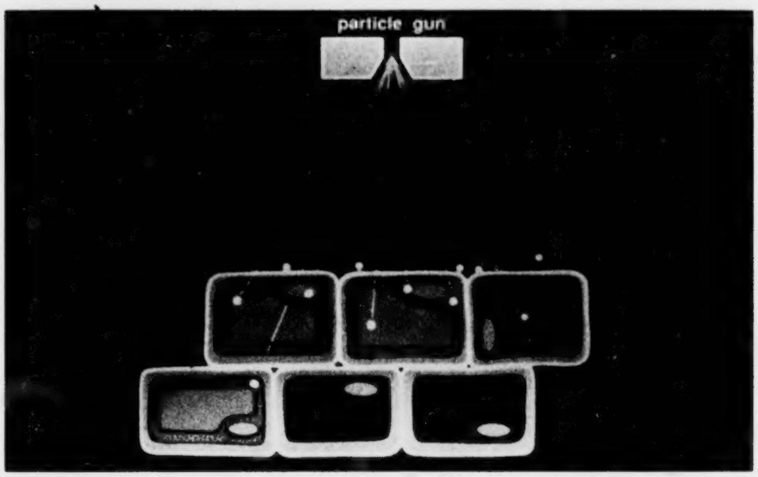
c. Microprojectile bombardment using a particle gun.

- Is a mechanical rather than chemical method
- DNA segments containing genes are bonded to microscopic metal particles (microprojectiles).
- DNA-bonded particles are loaded into a .22-caliber blank cartridge and fired in a vacuum chamber onto cells to be transformed.

Information Sheet

- A small portion of the cells will take up the foreign DNA and replicate it with their own DNA.

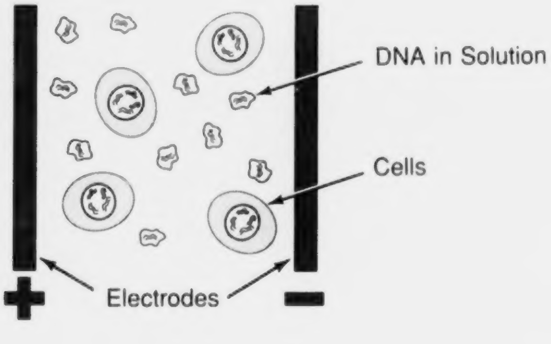
Figure 15—Microprojectile bombardment



d. Electroporation

- High voltage, short duration electrical pulses are used to generate high energy field strengths (5-55kV/cm) which cause transient pores to form in cells.
- DNA outside the cell will enter the cell through these pores.
- Once the electrical pulse stops, the pores in the cell close.
- The cells are grown under selective conditions to isolate cells that were able to take up the DNA from those that did not take up the DNA.

Figure 16—Electroporation



Information Sheet

11. Sorting DNA by gel electrophoresis

a. Is based on applying an electrical charge and moving negatively-charged DNA molecules toward a positively-charged terminal.

b. Uses a gelatin-like material that has uniform openings (pores) and rigid structure that allows passage of molecules.

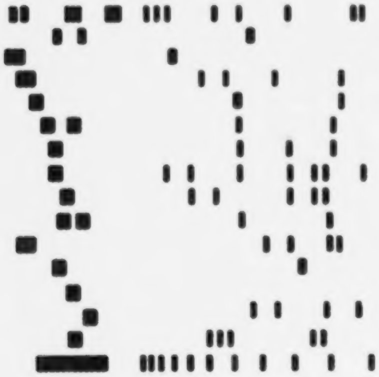
- Pores in gel act like a sieve and restrict passage of larger pieces of DNA.
- Changing the type of gel or changing the concentration of the ingredients can change the pore size so precise sizing of DNA pieces can be accomplished.

c. Smaller pieces of DNA move more rapidly because of their smaller mass and relatively greater charge.

d. After a period of time, bands of DNA of the same size will form.

e. Stains are used to make the bands of DNA visible.

Figure 17—DNA bands



f. Specific size of DNA pieces can be determined by the location of the band.

g. Can be used to determine the presence of a piece of recombined DNA.

- The recombined piece will separate as a distinct band.
- Presence of the band shows that the recombined DNA was present in the DNA sample tested.
- Absence of the band indicates that transformation did not take place.

h. Purified DNA can be extracted from the gel and used to create more recombined DNA.

Genetics and Genetic Engineering
Unit 2

Assignment Sheet 1—Make a Model of a DNA Molecule

Name ______________________ Overall Rating __________

Evaluation criteria	Rating
Support stand is erect and sturdy	______
Support tabs are correctly placed	______
Angle between support tabs is correct	______
Nucleotide sequence is correct	______
Nucleotide bonds are correct	______
Deoxyribose-phosphate backbone strips are correctly coiled and attached	______

Introduction: The unique structural arrangement of DNA allows for storage and transmission of all genetic information from one generation to another. This model will be a visual representation of DNA's structure.

Materials:

- 1 — 6-inch square block of 2" x 6" x 6" wood
- 1 — 24-inch long ¼" diameter dowel
- 2 — sheets of tabs (included)
- 2 — approx. 4-foot long strips of computer paper edging
- Tacky glue or glue stick
- Scissors
- Protractor
- Electric drill and ¼" drill bit

Directions: Build a model of a DNA molecule by using the following steps. Refer to the photograph of the completed model at the end of the procedure steps for a better idea of what you are trying to build.

Note: This model will be used in Assignment Sheet 2.

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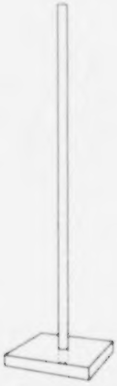
Assignment Sheet 1

A. Build the support stand.

1. Drill a ¼" hole in the center of the wood block.
2. Insert the dowel in the hole and stand the assembly upright.

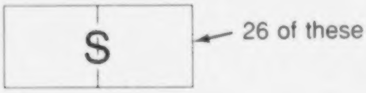
Figure 1—Support stand



B. Attach the support tabs to the dowel.

1. Cut 26 support tabs labeled "S" from the sheet provided. Cut on the solid lines surrounding the "S". Do not cut on the dashed line.

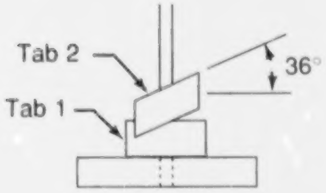
Figure 2—Support tabs



Assignment Sheet 1

2. Align the dashed "S" line with the long axis of the dowel and glue the first tab in place at the bottom of the dowel.

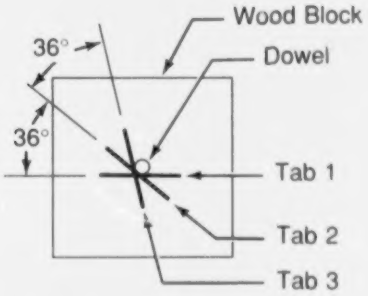
Figure 3—Side view of support tab placement



3. Use a protractor to rotate the second tab 36 degrees from the first and glue it in place just above the first tab. *This 36-degree rotation mimics the actual rotation of a DNA molecule where 10 nucleotide base pairs make one full rotation—36° × 10 = 360° (one full rotation).*

Note: A copy of a modified protractor is included on the last page of this assignment. Use it for measuring the 36-degree rotation if a protractor is not available.

Figure 4—Top view



4. Continue attaching all 26 of the tabs rotating each 36 degrees from the one below it.

Assignment Sheet 1

C. Attach the nucleotide bases in the correct sequence.

1. Cut out 17 "T-A" tabs from the sheets provided. Do not cut on the dashed line.
2. Cut out 9 "C-G" tabs from the sheets.
3. Starting at the bottom, attach the nucleotide tabs to the support tabs in the exact arrangement shown in the diagram to the right. (Figure 5)

   Note: The diagram is linear but your model will rotate. Keep track of left and right as you move up the model. The easiest way to do this is to rotate the stand as you move up.

D. Attach the deoxyribose-phosphate "backbone" to the ends of the nucleotide bases.

1. Bend each of the nucleotide base tabs back 90 degrees at the dashed line.
2. Glue one strip of computer paper edging to each tab end on the right side. This will coil upward as you progress.
3. Repeat step 2 with the other computer strip for the left side.

E. This model represents a piece of DNA showing the nucleotide bonds and the deoxyribose-phosphate backbone. The double helix coiled structure is a reasonably accurate representation of the actual structure of a DNA molecule.

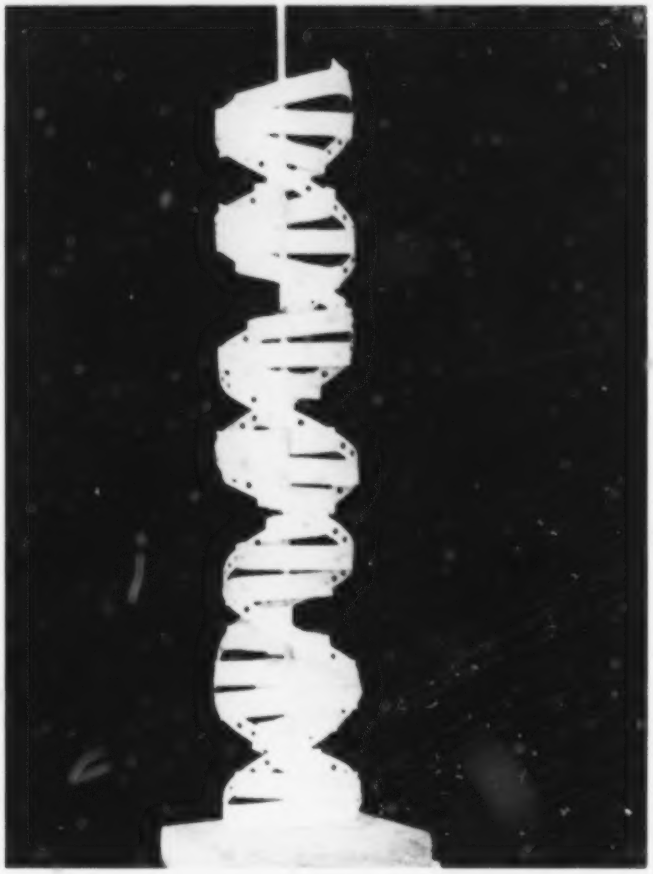
Figure 5—Nucleotide Sequence for Model

T	>	A
C	(	G
T	>	A
T	>	A
C	(	G
G	)	C
T	>	A
A	<	T
C	(	G
T	>	A
T	>	A
A	<	T
A	<	T
G	)	C
C	(	G
A	<	T
T	>	A
A	<	T
A	<	T
C	(	G
G	)	C
T	>	A
T	>	A
A	<	T
A	<	T
C	(	G

Assignment Sheet 1

Note: This is how your model should look. Write your name on the bottom of the model. Store your model in a safe place for use in Assignment Sheet 2.

Figure 6—DNA model



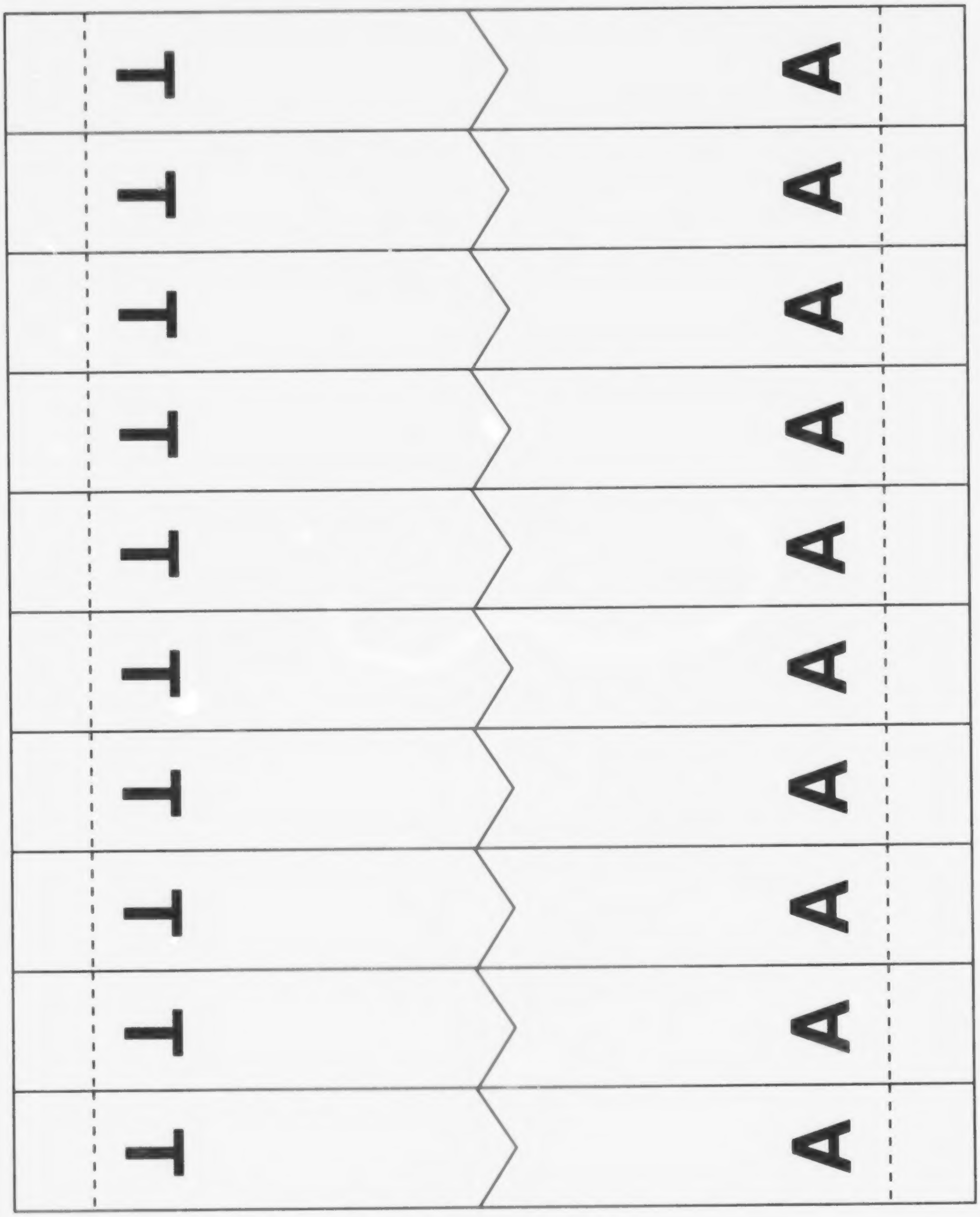
Assignment Sheet 1

Support Tabs

S	S	S
S	S	S
S	S	S
S	S	S
S	S	S
S	S	S
S	S	S
S	S	S
S	S	S

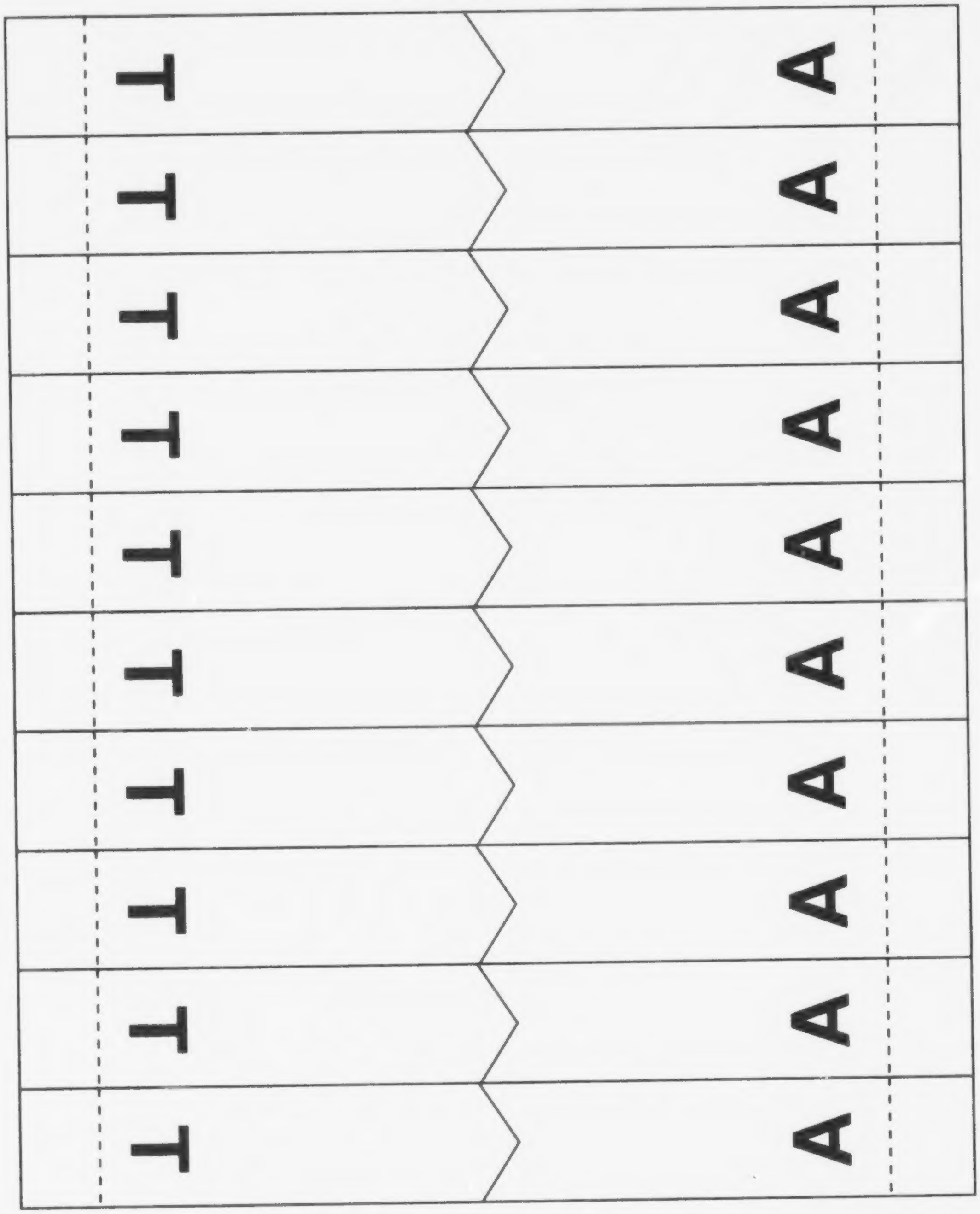
Assignment Sheet 1

Nucleotide "T-A" tabs


T
A
T
A
T
A
T
A
T
A
T
A
T
A
T
A
T
A
T
A

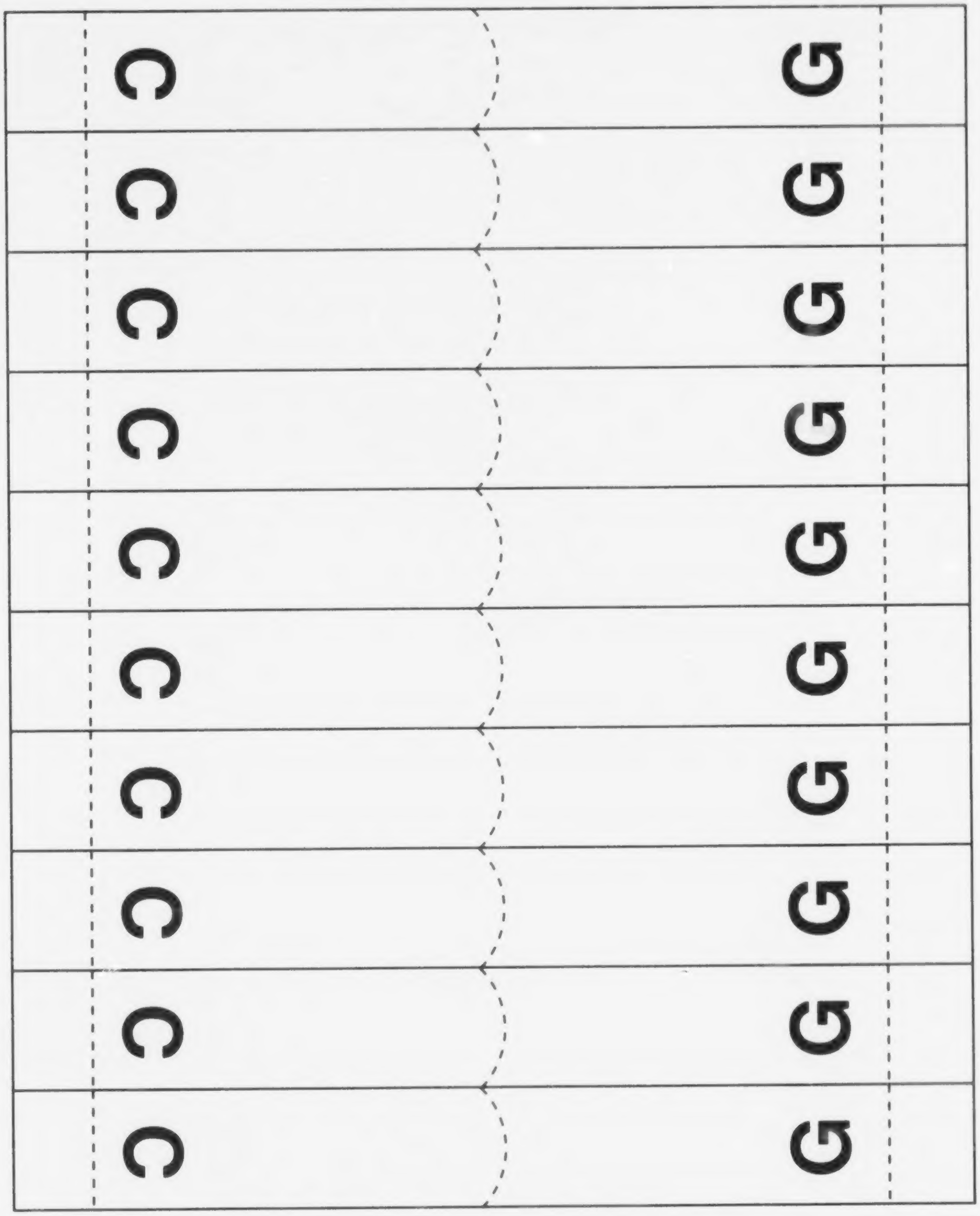
Assignment Sheet 1

Nucleotide "TA" tabs


T
A
T
A
T
A
T
A
T
A
T
A
T
A
T
A
T
A
T
A

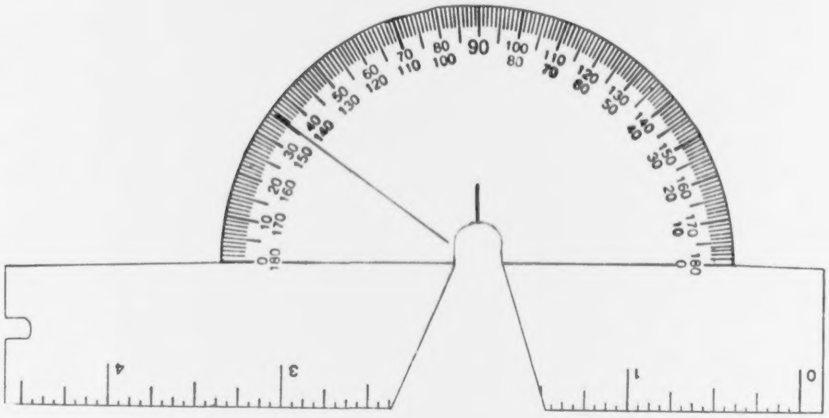
Assignment Sheet 1

Nucleotide "CG" tabs


C G
C G
C G
C G
C G
C G
C G
C G
C G
C G

Assignment Sheet 1

Modified Protractor — Cut out and place notch around dowel. Use marked line to make 36-degree rotation.


0
180
10
170
20
160
30
150
40
140
50
130
60
120
70
110
80
100
90
100
80
110
70
120
60
130
50
140
40
150
30
160
20
170
10
180
0
4
3
1
0

Genetics and Genetic Engineering
Unit 2

Assignment Sheet 2—Genetically Engineer a Model DNA Molecule

Name ______________________ Overall Rating ________

Evaluation criteria	Rating
Recognition sequence for Hpa 1 located	______
Cutting points for Hpa 1 located	______
Recognition sequence for Eco RI located	______
Cutting points for Eco RI located	______
DNA piece removed at correct points	______
Nucleotide bonds are correct on newly designed piece of DNA	______
Sequence of introduced piece of DNA matches at the cutting points	______
Engineered model completed and intact	______

Introduction: Genetic engineering is rapidly becoming a common method of changing genetic instructions and the function of organisms. "Engineering" this model is a visual method of showing how genetic engineering is accomplished.

Materials:

- DNA model from Assignment Sheet 1
- Tacky glue or glue stick
- Scissors
- 2 marking pens (1 green, 1 black)
- 2 - 24" strips of computer paper edging

Directions: Locate and remove a section of the DNA model using the following steps. Replace the section with a new set of nucleotides of your own design.

A. Locate and mark the recognition sequence and cutting points for the restriction enzyme Hpa 1.

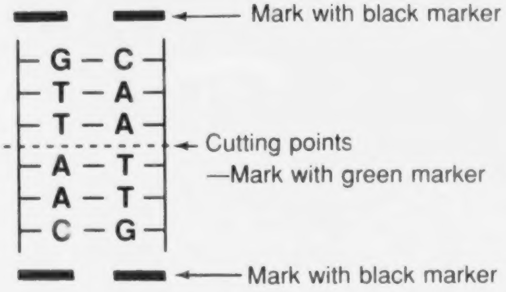
   Note: Hpa 1 is an actual restriction endonuclease that cuts DNA at the same site as demonstrated on your model.

   1. Locate the sequence on your model that is recognized by Hpa 1. Follow Figure 1 and mark the beginning and ending of this sequence on your model using the black marking pen.

Assignment Sheet 2

2. Locate the cutting points for Hpa 1 on your model and mark them with the green marker.

Figure 1—Recognition sequence for Hpa 1


Mark with black marker
G – C
T – A
T – A
Cutting points
—Mark with green marker
A – T
A – T
C – G
Mark with black marker

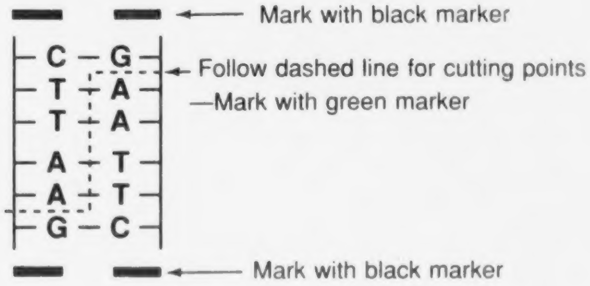
B. Locate and mark the recognition sequence and cutting points for the restriction enzyme Eco RI.

Note: Eco RI is also an actual restriction endonuclease used in cutting DNA molecules.

1. Locate the sequence recognized by Eco RI. Follow Figure 2 and locate the same sequence on your model. Mark the beginning and ending of this sequence with your black marking pen.

2. Mark the cutting points for Eco RI on your model using the green marking pen.

Figure 2—Recognition sequence for Eco RI


Mark with black marker
C – G
Follow dashed line for cutting points
—Mark with green marker
T – A
T – A
A – T
A – T
G – C
Mark with black marker

Assignment Sheet 2

C. Remove the section of the DNA molecule between the enzyme cutting points.

1. Cut the deoxyribose-phosphate backbone strips at the green marks.

2. Cut the nucleotide bonds at the green marks.

3. Cut any remaining nucleotides between the green marks and discard the piece of DNA removed.

D. Design a new piece of DNA and build it into the model at the location where the old DNA was removed.

1. Replace any support tabs that you have cut with extras at the end of this assignment.

2. Attach nucleotide tabs of your choice with matching bonds.

3. Fill in all nucleotides until your model is complete.

4. Attach new deoxyribose-phosphate strands (computer paper edging) to fill in the "backbone".

   Note: You are now a "model genetic engineer". In an actual experiment this piece of DNA would change the genetic instructions and a different protein would be formed as a result.

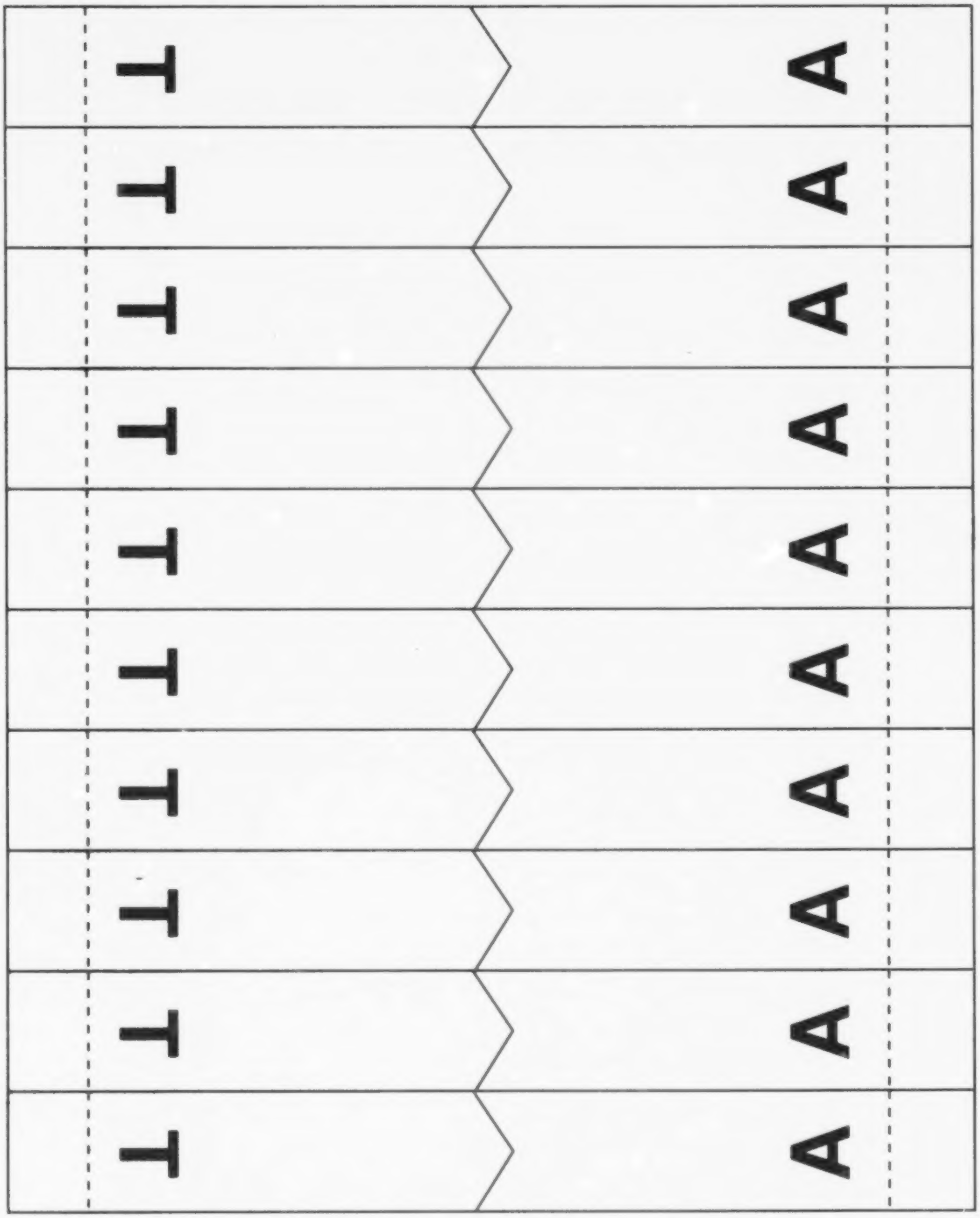
Assignment Sheet 2

Extra Support Tabs

S	S	S
S	S	S
S	S	S
S	S	S
S	S	S
S	S	S
S	S	S
S	S	S
S	S	S

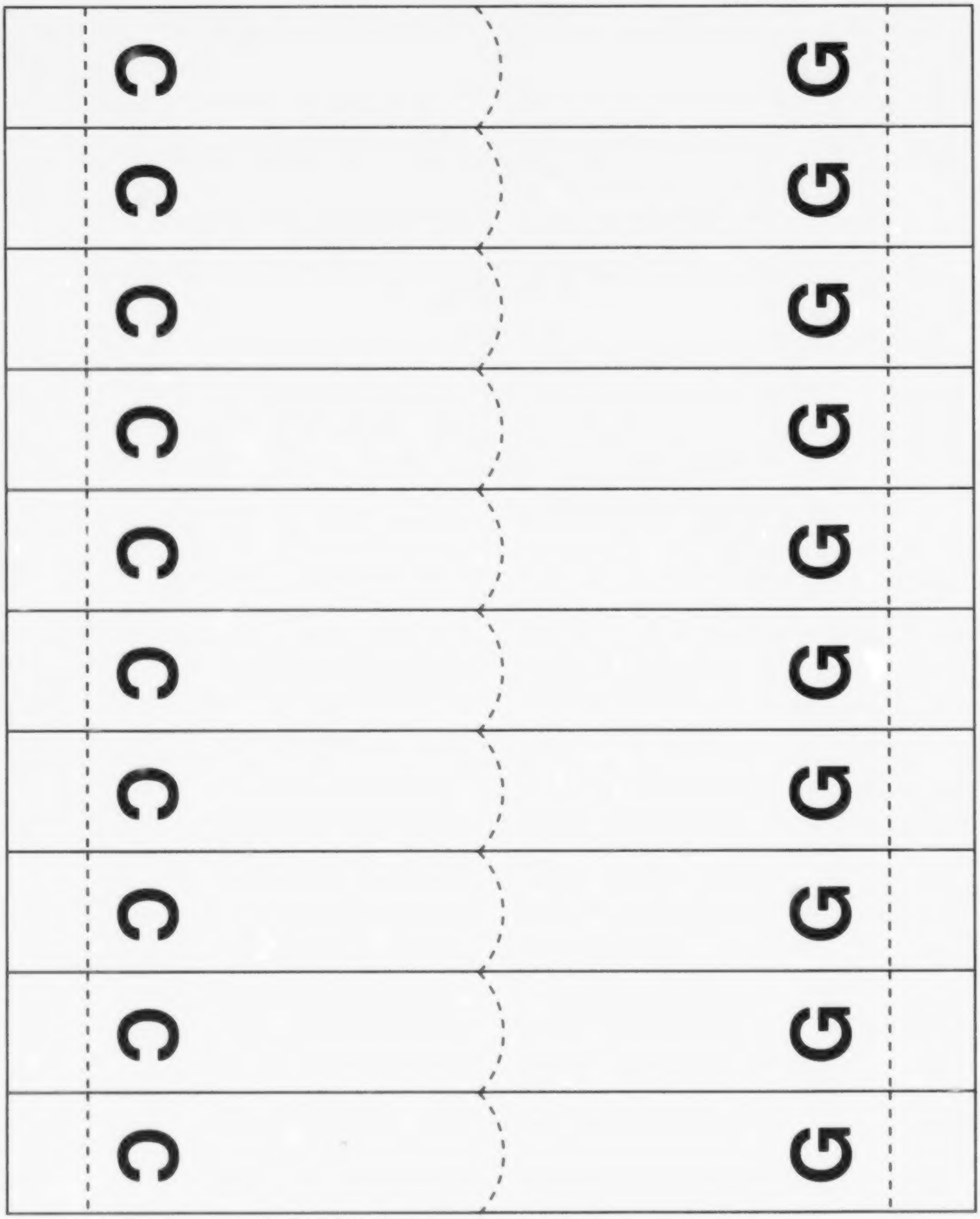
Assignment Sheet 2

Extra Nucleotide "T-A" tabs


T
A
T
A
T
A
T
A
T
A
T
A
T
A
T
A
T
A
T
A

Assignment Sheet 2

Extra nucleotide "CG" tabs


C
G
C
G
C
G
C
G
C
G
C
G
C
G
C
G
C
G
C
G

Genetics and Genetic Engineering
Unit 2

Laboratory Sheet 1—Extract DNA from Cells

Name ______________________________ Overall Rating __________

Evaluation criteria	**Rating**
All items on completion checklist checked off	______
Correct procedure followed	______
DNA product obtained	______
Laboratory notebook properly maintained	______
Questions on student instructions answered correctly	______
Laboratory report properly completed	______

Introduction. This activity results in the actual extraction of a large quantity of DNA that can be seen as it winds around a glass rod. This duplicates one method used by scientists to isolate DNA.

Directions: Check off each item on the following completion checklist for DNA extraction as you complete it. Follow the procedure steps and answer the summary questions found in your biotechnology kit.

Note: Carolina Biological Supply Company Biotechnology Kit #17-1090, DNA Extraction, is recommended. Other DNA extraction kits may be substituted.

Completion Checklist for DNA Extraction

☐ 1. Review the purpose of this experiment with your instructor. Write a statement of purpose in your laboratory notebook.

☐ 2. Go over each item of material with your instructor. Include this list in your laboratory notebook.

☐ 3. Review the laboratory procedure with your instructor. Record any changes in procedure in your laboratory notebook.

☐ 4. Perform the procedure steps listed in the student instructions for your kit. Record your observations in your laboratory notebook.

☐ 5. Show your extracted DNA to the instructor for evaluation.

☐ 6. Answer the questions included with your kit. Keep this with your laboratory notebook.

☐ 7. Write a laboratory report for this activity.

☐ 8. Turn in your laboratory notebook and laboratory report for evaluation.

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Genetics and Genetic Engineering
Unit 2

Laboratory Sheet 2—Transform Bacterial Cells

Name ______________________________ Overall Rating __________

Evaluation criteria	**Rating**
Read and discussed article on DNA transformation of *E. coli*	______
Recorded purpose of experiment in lab notebook	______
Used aseptic technique	______
Listed materials in lab notebook	______
Recorded procedural changes in lab notebook	______
Followed procedure	______
Recorded results in notebook	______
Successfully transformed bacteria	______
Completed lab report	______

Introduction: This activity is an actual genetic engineering exercise where bacteria that would normally be killed by exposure to an antibiotic are altered so they can resist the killing effect of the antibiotic.

Directions: Check off each item in the completion checklist as you complete it. Follow the directions in the checklist.

Note: Cabisco™ Biotechnology Colony Transformation Kit from Carolina Biological Supply Company is recommended. Other colony transformation kits may be substituted.

Completion Checklist for DNA Extraction

☐ 1. Read and discuss with your instructor — *Carolina Tips*. "DNA Transformation of *Escherichia coli*," March 1, 1988.

☐ 2. Record a statement of purpose for this experiment in your laboratory notebook.

☐ 3. Review the procedures for aseptic technique from Unit 1 and use them in this experiment.

☐ 4. Go over each piece of material with your instructor. Include a list in your laboratory notebook.

☐ 5. Review the procedure with your instructor. Record any changes in your laboratory notebook.

Laboratory Sheet 2

☐ 6. Follow the student instructions for the colony transformation kit and complete the activity. Record your observations in your laboratory notebook.

☐ 7. Evaluate your results and record your observations in the laboratory notebook.

☐ 8. Answer the study questions on the last page of the student instructions. Keep this with your laboratory notebook.

☐ 9. Write a laboratory report on this activity.

☐ 10. Turn in your laboratory notebook and laboratory report for evaluation.

Impacts of Biotechnology
Unit 3

Objective Sheet

Unit Objective

After completing this unit, the student should be able to discuss opportunities, impacts, and public issues concerning biotechnology. The student should demonstrate these competencies by completing the assignment sheets and laboratory sheet and by scoring a minimum of 85 percent on the written test.

Specific Objectives

After completing this unit, the student should be able to:

1. Match terms related to impacts of biotechnology with the correct definitions.
2. List benefits of biotechnology.
3. List concerns about biotechnology.
4. Complete statements about the environmental impacts of biotechnology.
5. Match regulatory agencies or laws with the correct types of controls used for biotechnology.
6. List ethical issues impacting biotechnology.
7. Distinguish between types of companies in the biotechnology industry.
8. List work areas in agricultural biotechnology.
9. Answer questions about positions, salary ranges, and educational requirements for careers in biotechnology.
10. Respond to concerns about biotechnology. (Assignment Sheet 1)
11. Conduct an opinion poll about biotechnology. (Assignment Sheet 2)
12. Write a position paper on the ethics of biotechnology. (Assignment Sheet 3)
13. Evaluate salt concentration as an environmental factor affecting plant growth. (Laboratory Sheet 1)

Impacts of Biotechnology
Unit 3

Suggested Activities

Instructional Plan

1. Read the unit carefully and plan for instruction. Study the specific objectives and develop your presentation.
2. Review teaching suggestions and plan classroom and laboratory activities.
3. Plan presentation for enrichment of exceptional students as well as accommodation of special needs students.
4. Obtain videotapes and materials to supplement instruction of this unit. See ordering information in the Suggested Supplemental Resources section.
5. Prepare for the laboratory activity by obtaining materials and arranging for a plant growth facility. See alternative approaches in the Teaching Suggestions section. You may want to start this activity early in the unit because about 6 weeks are required for completion.
6. Review instructions for evaluating student performance and make copies of unit evaluation form.
7. Provide students with the unit of instruction. Review objectives with them. Inform them about materials included in the unit test.
8. Make copies of any teacher supplements that you want to provide to the students. These can be used for further research or discussion. Teacher supplements for this unit include the following:

   Teacher Supplement 1—Opinions About Biotechnology
   Teacher Supplement 2—Pending Environmental Applications of Genetic Engineering
   Teacher Supplement 3—Lou Harris 1986 Survey Poll About Biotechnology
   Teacher Supplement 4—Sample Questions for Public Opinion Survey of Biotechnology

9. Discuss assignment sheets and laboratory sheet with students. Review criteria for evaluation of these activities.
10. Discuss the use of the unit evaluation form with students. Select and discuss the rating scale that will be used for student evaluation.
11. Give written test.
12. Compile assignment sheet ratings, laboratory sheet rating, and written test scores on the unit evaluation form. Include any additional assignments.
13. Reteach and retest as required.

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Suggested Activities

Teaching Suggestions

Note: Skill areas appearing in bold face type in the teaching suggestions refer to the academic and workplace skills identified by the American Society for Training and Development (ASTD) and the U.S. Department of Labor and adapted by MAVCC.

1. Invite a guest speaker or assemble a panel to discuss the ethics of biotechnology. Sources could include attorneys, farmers and ranchers, scientists, and clergy. **Adaptability skills, communication skills, group effectiveness skills**

2. Expand the survey of opinions about biotechnology from Teacher Supplement 1 into a class project. Results could be compiled and printed in a newsletter, school paper, or local newspaper. **Adaptability skills, communication skills, group effectiveness skills**

3. Whether or not you use Assignment Sheet 1 on concerns about biotechnology, it is advisable to review responses with students to demonstrate scientific care and efforts to deal with these concerns. See answer sheet for Assignment Sheet 1.

4. Help students develop suitable questions for their opinion poll in Assignment Sheet 2. You may want students to use the questions in Teacher Supplement 4 or develop different questions. Make sure they survey a wide variety of people to get a representative view of the "public." **Communication skills, group effectiveness skills**

5. Position papers in Assignment Sheet 3 can be developed into a class project. Develop these into a public forum, debate, or presentation to other students or at a public gathering. **Communication skills, group effectiveness skills**

6. Search for any biotechnology experiments or proposals planned or underway in your community or state. Use information about these to spark discussion about their validity, environmental hazard, and so forth. Invite the persons conducting the experiment to participate. *New Developments in Biotechnology 3* explains several examples of local projects starting on page 49.

7. Several alternatives can be used in Laboratory Sheet 1 on environmental effects on plants. Wisconsin Fast Plants has kits for salt tolerance and acid rain. You may design other pollutants into the experiment especially if your community is experiencing a pollution problem. Natural soils that have salinity, acidity, oil spill problems, and so forth can be designed into this experiment. **Foundation skills—science**

Suggested Activities

8. Encourage motivated students to continue exploration of issues and experimentation on their own. Encourage them to develop demonstration activities, science fair activities, productive enterprises, and to apply for Agriscience Student of the Year Awards through the FFA. *The Science Workbook* from The College of Agriculture at Ohio State University, 2120 Fyffe Road, Columbus, OH 43201 (Phone 614-422-1734) has examples of several experiments that students have developed. **Adaptability skills, foundation skills—science**

9. Hold a biotechnology career fair. Have scientists, counselors, prospective employers, job service, and extension personnel participate. **Personal and career development skills**

10. Have students interview and compile a job profile on someone involved in a career in an area of biotechnology. **Personal and career development skills, communication skills**

11. Have students select an employment area in biotechnology that interests them, research that area, and prepare their own job profile. **Personal and career development, foundation skills—reading and writing**

Resources Used in Developing This Unit

1. *Agricultural Biotechnology and the Public*. Washington, DC: United States Department of Agriculture, 1988.

2. *Biotechnology at Work*. Washington, DC: Industrial Biotechnology Association, 1989.

3. *Biotechnology in Perspective*. Washington, DC: Industrial Biotechnology Association. Hobsons Publishing inc., 1988.

4. Brock, Robert. *The Challenge of Biotechnology*. Denver: Monsanto Company.

5. Doyle, Jack. *Altered Harvest*. New York: Penguin Inc., 1985.

6. Gasser, Charles S. and Robert T. Fraley. "Genetically Engineered Plants for Crop Improvement," *Science*, Vol. 244, June 16, 1989.

7. *Genetic Engineering of Plants*. National Research Council. Washington, DC: National Academy Press, 1986.

8. Mellor, John W. and Frank Z. Rieley. "Expanding the Green Revolution," *Issues in Science and Technology*. Fall, 1989.

Suggested Activities

9. *New Developments in Biotechnology.*

    a. *2: Public Perceptions of Biotechnology*, 1987.
    b. *3: Field-Testing Engineered Organisms*, 1988.
    c. *4: U.S. Investment in Biotechnology*, 1988.

    Congress of the United States, Office of Technology Assessment, Washington, DC: U.S. Government Printing Office.

10. Olson, Steve. *Biotechnology, An Industry Comes of Age.* Washington, DC: National Academy Press, 1986.

11. Thompson, Dick. "The Most Hated Man in Science." New York: *Time Magazine*, Vol. 134, No. 23, Dec. 4, 1989.

12. *Wisconsin Fast Plants Manual.* University of Wisconsin, Madison, WI. Distributed by Carolina Biological Supply, 1989.

Suggested Supplemental Resources

1. Videotapes (VHS)

    a. *Connections: Animals, People, and Biotechnology.* (18 min.)

    b. *Of the Earth: Agriculture and the New Biology.* (28 min.)

    c. *Delicate Balance: Understanding Human Health Through Biotechnology.* (28 min.)

    d. *Biotechnology Serving Human Needs.* (18 min.)

    Note: (a) and (b) may be repeats from Unit 1 but may be more meaningful now that students have had more exposure to biotechnology concepts.

    a-d are available from:

    Industrial Biotechnology Association
    1625 K Street, NW
    Washington, DC 20006
    202-857-0244

    e. *Lights Breaking: Ethical Questions About Genetic Engineering.* (59 min.) Discussion by people from various backgrounds about the social implications of biotechnology. Available from:

    Bullfrog Films
    Oley, PA 19547
    215-779-8226

Suggested Activities

2. Filmstrip and cassette tape—*Issues in Genetic Engineering*. Available from:

   National Geographic Society
   Educational Services, Dept. 5295
   Washington, DC 20036
   800-368-2728

3. Booklets

   a. *Biotechnology in Perspective*

   b. *Biotechnology at Work*

   c. *Answers to Commonly Asked Questions About Biotechnology Regulation*

   d. *Careers in Biotechnology*

   e. *Survey of State Government Legislation on Biotechnology*

      a-e are available from:

      Industrial Biotechnology Association
      1625 K Street, NW
      Washington, DC 20006
      202-857-0244

   f. *New Developments in Biotechnology 2, 3, and 4*. Helpful resources for both teachers and students. Available from:

      Superintendent of Documents
      Government Printing Office
      Washington, DC 20402-9325
      202-783-3238

Instructions For Evaluating Student Performance

Assignment Sheets — Be sure the student understands the criteria on which the evaluation is based. Assign a point value to each criterion and convert the total points to a percentage for grading.

Laboratory Sheets — Rate both process and product. The process should be based on the evaluation criteria for the laboratory activity. Observe the student during the laboratory activity and complete the rating by assigning a point value to each criterion and converting the point total to a percentage for grading. The laboratory product should be based on the completed laboratory report.

Suggested Activities

Performance evaluation can be based on the combined process and product evaluation. A suggested performance evaluation key is given below:

Performance level	Evaluation
90-100%	Skilled — Able to perform laboratory activity and arrive at a sound conclusion with no additional practice.
80-90%	Moderately Skilled — Able to perform most laboratory activities and arrive at reasonable conclusions.
70-80%	Limited Skill — Can perform some laboratory activities and work toward conclusions but needs additional practice in some areas.
0-70%	Unskilled — Not able to follow procedure and reach a satisfactory conclusion. Performance and evaluation must be repeated.

Impacts of Biotechnology
Unit 3

Answers to Assignment Sheets

Assignment Sheet 1

Note: Answers will vary considerably and any answer that is logical and supported should be accepted. The following are possible responses.

a. EPA regulations for environmental release of organisms are stringent and harmful release is unlikely.

b. Laboratory experiments are conducted under carefully controlled conditions to prevent escape of organisms. Industry and researchers are very concerned about escape, and design safeguards into facilities and experiments.

c. Controlled experiments and field trials evaluate dominance and include means for controlling dominant species.

d. Required identification, labeling, and controlled release of resistant organisms are safeguards used to prevent environmental problems.

e. Loss of genetic base is a concern of scientists, and efforts are underway to preserve as much genetic stock as possible. These include seed repositories, maintenance of cultures, and preservation of native species.

f. Present laws already provide some protection against discriminatory job and insurance applications. Future legislation is likely to be protective of individual rights in genetic discrimination.

g. Deformities and lethal consequences of genetic research are a major concern of the scientific community. Such results would be very damaging to future research. Most research facilities have strong policies and prohibitions against research that has these possible consequences.

Assignment Sheet 2—Evaluation should be based on the criteria identified on the assignment sheet. Significance should be placed on successful completion of the survey and interpretation of the results in the conclusion.

Assignment Sheet 3—Evaluation should be based on the criteria identified on the assignment sheet. Significance should be placed on their ability to clearly present a position on their ethical stand on biotechnology.

Impacts of Biotechnology
Unit 3

Answers to Written Test

1.

a.	6	f.	15
b.	9	g.	1
c.	14	h.	13
d.	2	i.	11
e.	7	j.	3

2. a. Benefits to plant science—Any three of the following:

   (1) Rapid development of new varieties
   (2) Addition of new capabilities to existing plants such as drought tolerance or insect and disease resistance
   (3) Improvement of nutritional quality of plant materials
   (4) Development of herbicide-resistant crop plants
   (5) New methods to eliminate or reduce environmental effects of hazardous compounds
   (6) Improved nitrogen-fixation ability and reduction in commercial fertilizer application
   (7) Increased frost resistance

   b. Benefits to animals and humans—Any three of the following:

   (1) Development of specific vaccines for diseases such as calf diarrhea and hoof and mouth disease
   (2) Development of specific diagnostic tests such as monoclonal antibodies for drug testing
   (3) Alteration of gene action to control some heritable disease tendencies such as cancer
   (4) New sources of useful products such as insulin produced by engineered bacteria
   (5) Production of scarce materials such as the anti-viral compound interferon
   (6) "DNA fingerprinting" for identification and paternity concerns
   (7) Hormone therapy such as bovine somatotropin (BST) for increased milk production in dairy cattle
   (8) Animal selection based on genetic indicators
   (9) Production of identical offspring using embryo splitting and transfer

3. Any three of the following:

   a. Release of organisms that could harm the environment
   b. Escape of undesirable organisms from experimental studies
   c. Development of dominant organisms that overwhelm desirable organisms

Answers to Written Test

d. Development of resistant organisms that become difficult to control in the environment
e. Loss of large genetic base (pool) by removing genes through genetic engineering
f. Identification of genetic defects that may be used to discriminate against individuals in job selection or acceptance for insurance
g. Genetic alteration that may cause deformities or death

4. a. Potential
b. Reproduce
c. Their surroundings
d. Some, no
e. Federally funded

5. a. 1
b. 6
c. 8
d. 3
e. 4
f. 7

6. Any six of the following:

a. Is biotechnology a legitimate science, or are we "playing God?"
b. Will biotechnology help relieve hunger and poverty, or will it help only the rich?
c. Is this technology useful for countries that do not raise enough food to feed themselves?
d. Will biotechnology cause more environmental problems, or will it help relieve them?
e. Will focus of biotechnology research be toward commercial profitability or relief of human suffering? Can it be both?
f. Will this technology be controlled by large conglomerates or through public representation?
g. Will biotechnology benefit large production enterprises alone, or will small units be able to benefit as well?
h. Is regulation sufficient to prevent disastrous problems from arising?
i. Is this science too complicated for reasonable use at the production level?
j. Is international structure sufficient to assure equitable access to this technology?
k. Will trade barriers prevent fair market access?
l. Are biotechnologies compatible with good conservation practices?
m. Do patent and secrecy laws give excessive control of living processes?
n. Will university-industry research agreements direct research away from public good and toward the most profitable alternatives?
o. Will biotechnology narrow genetic pools and reduce genetic diversity?
p. Should we adopt high production technologies in the face of surplus commodities?

Answers to Written Test

q. Do we have the right to manipulate human genes?
r. Is genetic manipulation to correct human genetic disease acceptable?
s. Is recombining genes to develop a "super" animal or human legitimate?
t. Is somatic cell (not passed on to the next generation) gene manipulation acceptable for animals? for humans?
u. Is gamete or reproductive cell gene manipulation acceptable for animals? for humans?
v. Should we compensate people who have been adversely affected by biotechnology changes?

7. b

8. Any six of the following:

- Enzymes
- Food additives
- Animal feed supplements
- Improved and new plant varieties
- Pesticides
- Herbicides
- Vaccines
- Plant growth hormones
- Fertilizers
- Nitrogen fixation
- Diagnostic reagents
- Animal genetics
- Quality control
- Clinical research
- Regulatory affairs
- Manufacturing
- Production
- Information systems
- Marketing
- Sales
- Administration

9. a. Project manager or technical service director
b. B.S. or M.S.
c. PhD

Impacts of Biotechnology
Unit 3

Written Test

Name ______________________________ Score ______________

1. Match the terms on the right with the correct definitions.

______a. The complex of climatic, soil, and life systems that acts on an organism or an ecological community and ultimately determines its form and survival

______b. General term for any agent used to kill undesirable organisms

______c. Subject to the effect of a toxic or disease-producing agent

______d. A device used to detect a chemical, biological, or physical change that has a living system as one component of the device

______e. Principles of conduct governing an individual or a group about what is right or wrong

______f. Relating to the treatment of disease or disorders by remedial agents or methods

______g. A medical product derived from living sources, usually referring to a vaccine

______h. Ability to withstand unfavorable environmental conditions

______i. Mathematical calculation of the chance that a given event will occur

______j. An agent used to detect disease

1. Biological
2. Biosensor
3. Diagnostic
4. Ecology
5. Ecosystem
6. Environment
7. Ethics/morals
8. Insecticide
9. Pesticide
10. Pharmaceutical
11. Probability
12. Reagent
13. Resistant
14. Susceptible
15. Therapeutic

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Written Test

2. List three benefits of biotechnology to plant science and three benefits to animals and humans.

   a. Benefits to plant science

      (1) ____

      ____

      (2) ____

      ____

      (3) ____

      ____

   b. Benefits to animals and humans

      (1) ____

      ____

      (2) ____

      ____

      (3) ____

      ____

3. List three concerns about biotechnology.

   a. ____

   ____

   b. ____

   ____

   c. ____

   ____

Written Test

4. Circle the correct word or phrase to complete statements about the environmental impacts of biotechnology.

   a. Genetically engineered organisms have the (potential, probability) for harming ecosystems.

   b. An environmental risk factor for genetically engineered organisms is whether it will (repose, reproduce) in the environment.

   c. Research into the interactions of organisms with (other organisms, their surroundings) is key to limiting problems with environmental release.

   d. The Congressional Office of Technology Assessment concludes that "there is (no, some) reason to be cautious, but (no, some) cause for alarm at the prospect of environmental release".

   e. Recommendations from the Recombinant DNA Advisory Committee of the National Institutes of Health are binding only for (federal agency, federally funded) research.

5. Match the regulatory agencies or laws on the right with their types of controls for biotechnology.

   ______ a. Controls use of pesticides, chemicals, and microorganisms with environment effects

   ______ b. Provide legal recourse against unauthorized use of a protected product or process

   ______ c. Regulates some animal and plant products and pests

   ______ d. Establishes guidelines for federally-funded research

   ______ e. Provide 17 year exclusive rights for manufacture, use, and sale of a product or process

   ______ f. Enacts laws to regulate all aspects of biotechnology

   1. Environmental Protection Agency (EPA)
   2. Food and Drug Administration (FDA)
   3. Recombinant DNA Advisory Committee (RAC) of the NIH
   4. Patent laws
   5. State and local government
   6. Trade secrecy laws
   7. United States Congress
   8. United States Department of Agriculture (USDA)

Written Test

6. List six ethical issues impacting biotechnology.

   a. ____________________

   ____

   b. ____________________

   ____

   c. ____________________

   ____

   d. ____________________

   ____

   e. ____________________

   ____

   f. ____________________

   ____

7. Distinguish between the types of companies in the biotechnology industry by placing an "X" next to the description of large diversified companies.

   ______a. Start-up companies that began operation after 1976 to develop specific commercial products from biotechnology research.

   ______b. Established multiproduct firms using biotechnology research to develop marketable products.

8. List six work areas in biotechnology.

   a. ____________________
   b. ____________________
   c. ____________________
   d. ____________________
   e. ____________________
   f. ____________________

Written Test

9. Answer the following questions about positions, salary ranges, and educational requirements for careers in biotechnology.

   a. What position in biotechnology has an annual salary range of $45,000 to $80,000?

   ____

   b. What are educational requirements for a research assistant?

   ____

   c. A scientist or scientific director requires what educational degree?

   ____

Impacts of Biotechnology
Unit 3

Unit Evaluation Form

Student Name ______________________________ Unit Rating __________

Assignment Sheet 1—Respond to Concerns About Biotechnology Rating ______

Comments: ____

Assignment Sheet 2—Conduct an Opinion Poll about Biotechnology Rating ______

Comments: ____

Assignment Sheet 3—Write a Position Paper on the Ethics of Biotechnology Rating ______

Comments: ____

Laboratory Sheet 1—Evaluate Salt Concentration as an Environmental Factor Affecting Plant Growth Rating ______

Comments: ____

Written Test Scores

Pretest ______ Posttest ______ Other ______

Other ____

Teacher Signature ______________________________ Date __________

Student Signature ______________________________ Date __________

***Permission to duplicate this form is granted.**

Impacts of Biotechnology
Unit 3

Teacher Supplement 1—Opinions About Biotechnology

1. **Howard Schneiderman**, Monsanto Company—"I believe that genetic engineering is the most important advance in agricultural science of this century and can enhance both the productive efficiency of agriculture and the quality of our environment. It has the potential to increase vastly the economic competitiveness of American agriculture."

   SOURCE: "The Challenge of Biotechnology" by Robert Brock.

2. **Ray Thornton**, President of Arkansas State University—"To date, scientists have been able to pursue recombinant DNA research with remarkable freedom. The use of voluntary guidelines—rather than legislation—is a novel approach and is far more flexible than the regulations governing atomic, pharmaceutical, and chemical industries." He sees this freedom given to genetic engineering as a reflection of the public's confidence in the scientific community, of the public's belief that safety issues will be openly and honestly discussed.

   SOURCE: *Genetic Engineering of Plants*, National Academy Press, 1986.

3. **Jack Doyle** of the Environmental Policy Institute—"Biotechnology and genetic engineering hold enormous beneficial possibilities for agriculture, the environment, and food production worldwide. New knowledge can be applied in a beneficial direction. All that is necessary is the institutional will and political force to move the system in the right direction. Biotechnology—sent off in the wrong direction with large investments of capital and political ideology—could become equally obdurate and oppressive. Technologies are sometimes embraced without a full understanding of their power. We place a great deal of trust in business, government, and science to make the right decisions for us and our children. Yet because these decisions are often made by commercial and political interests for commercial and political reasons, it is often the public that is put at risk, rather than the corporation, the venture capitalist, or the career politician."

   Mr. Doyle also believes in strong regulatory procedures. "Farmers, consumers, and environmentalists must fight harder than ever before at the federal, state, and local level for new law, regulation, and public accountability across a broad range of policy areas that impinge on agriculture, the patent system, and science funding."

   SOURCE: *Altered Harvest* by Jack Doyle. Penguin Inc., 1985.

Teacher Supplement 1

4. **Martin Alexander** of Cornell University—"Many uncertainties surround environmental risk of release of genetically engineered organisms. It is impossible to calculate precisely how small the risk is. Claims of zero risk or great risk are inappropriate. Uncertainties will loom larger as more and more organisms are altered, as the number and kind of introduced genes grow, and as genetically engineered organisms are released into a wider range of environments. The degree of uncertainty is too large for me as an ecologist to feel comfortable with."

   SOURCE: Biotechnology: An Industry Comes of Age. National Academy Press. 1986.

5. **Jeremy Rifkin** of the Foundation on Economic Trends fears that society, inspired by science, will take a diminished view of human life as no more than a few strands of DNA. "This is a new technology that goes to the heart of our values. The end result could very well be a brave new world, very damaging to the human spirit."

   Mr. Rifkin actively opposes many technological advances on the grounds that society does not have enough input into decisions on the practicality, benefits, and dangers of these technologies. "My job is to point out some of the problems that might arise with new technologies. Scientists should show us how these new technologies work. Then society, not scientists, should decide if it wants to use them."

   SOURCES:
   - "Rifkin's Vow: 'We Will Not Be Cloned.'" *Newsweek*: May 26, 1986.
   - "Thank You, Jeremy Rifkin." *Forbes*: October 16, 1989.
   - "The Most Hated Man in Science." *Time*: December 4, 1989.

6. **Allen Dines**, Director of Business Development for the Agricetus Company, believes that biotechnology is not a dangerous science. He believes that present regulations developed by coordinated industry, science, and federal efforts are adequate for protection.

   SOURCE: *Agricultural Biotechnology and the Public*, Report on Conferences sponsored by USDA in 1988.

7. **Fred Davison**, President of the University of Georgia—"Risk must always be evaluated against the greater risk. In the case of biotechnology, there is no question in my opinion: the greater risk is the fear of a world with a rapidly increasing population and a decreasing resource base running out of that resource. Biotechnology is an answer to that risk. What we are talking about is making changes gene by gene in a very closely controlled way. Probably more closely controlled than natural selection that comes about in nature. So risk, there's always some, but the great risk is in not using these tools and using them immediately to guarantee that indeed we have a future."

   SOURCE: *Of The Earth* videotape sponsored by the Monsanto Company.

Teacher Supplement 1

8. **Fred Smith** of the Competitive Enterprise Institute—"Biotechnology may very well lower the need for energy drilling, chemical fertilizer and pesticide/herbicide production, land tilling, and other crop management activities, as well as storage and spoilage concerns; all of which have safety as well as economic consequences. Those gains are at risk if we continue to expand the political control over the evolution of biotechnology."

   Mr. Smith also feels that "private individuals held fully accountable for their actions" is the best approach to regulation. "Laws, procedures, risk of company and product reputation, concern for public welfare, private and scientific integrity, and threat of economic obliteration evoke satisfactory restraint and hold individuals in check."

   SOURCE: *Agricultural Biotechnology and the Public*, Report on Conferences sponsored by USDA in 1988.

Impacts of Biotechnology
Unit 3

Teacher Supplement 2—Pending Environmental Applications of Genetic Engineering

1. **MICROORGANISMS**

- **Bacteria as pesticides**. "Ice-minus" bacteria to reduce frost damage to agricultural crops.

  Bacteria carrying *Bacillus thuringiensis* toxin to reduce loss of corn crops to black cutworm.

  Mycorrhizal fungi to increase plant growth rates by improving efficiency of root uptake of nutrients.

- **Plant symbionts**. Nitrogen-fixing bacteria to increase nitrogen available to plants, and decrease need for fertilizers.

- **Toxic waste disposal**. Bacteria engineered to enhance their existing abilities to degrade compounds found in sludge in waste treatment plants.

  Bacteria engineered to enhance their abilities to degrade compounds in landfills, dumps, runoff deposits, and contaminated soils.

- **Heavy metal recovery**. Engineered enhancements possible to several species of bacteria now used to recover metals from low-grade ores (e.g., copper and cobalt).

- **Pollution control**. Possible increased utility of bacteria in purifying water supplies of phosphorus, ammonia, and other compounds.

- **Viruses as pesticides**. Insect viruses with narrowed host specifity or increased virulence against specific agricultural insect pests, including cabbage looper, pine beauty moth, cutworms, and other pests.

  Myxoma virus modified so as to restore its virulence against rabbits (which became resistant during early biocontrol efforts in Australia).

- **Viruses as vaccines**. Vaccines against human diseases including:

  — hepatitis A and B
  — polio
  — herpes simplex (oral and genital)
  — malaria
  — acquired immunodeficiency syndrome
  — rabies
  — respiratory syncitial virus

Vaccines against animal diseases including:

- swine pseudorables
- swine rotavirus
- vesicular stomatitis (cattle)
- foot and mouth disease (cattle)
- bovine rotavirus
- rabies (cattle, other mammals)
- sheep foot rot
- infectious bronchitis virus (chickens)
- avian erythroblastosis
- sindbis virus (sheep, cattle, chickens)

- **Multivalent vaccines**. Vaccines possible for antigenically complex diseases such as:
    - malaria
    - sleeping sickness
    - schistosomiasis

2. PLANTS

- **Herbicide resistance or tolerance to:**

Glyphosate
Atrazine
Sulfonylurea (chlorosulfuron and sulfometuron)
Imidazolinone
Bromoxynil
Phosphinotricin

- **Disease resistance to:**

Crown gall disease (tobacco)
Tobacco mosaic virus (and related viruses)
Potato leaf roll virus

- **Pest resistance**

BT-toxin-protected crops, including tobacco (principally as research tool) and tomato.

Seeds with enhanced anti-feedant content to reduce losses to insects while in storage.

Teacher Supplement 2

- **Enhanced tolerance to environmental factors, including:**

  Salt
  Drought
  Temperature
  Heavy metals

- **Nitrogen-fixation enhancements**

  Nonlegumes enhanced to fix nitrogen, independent of association with symbiotic bacteria.

- **Engineered marine algae**

  Algae enhanced to increase production of such compounds as B-carotene and agar, or to enhance ability to sequester heavy metals (e.g., gold and cobalt) from seawater.

- **Forestry**

  Trees engineered to be resistant to disease or herbicides, to grow faster, or to be more tolerant to environmental stresses.

3. **ANIMALS**

- **Livestock and poultry**

  Livestock species engineered to enhance weight gain or growth rates, reproductive performance, disease resistance, or coat characteristics.

  Livestock animals engineered to function as producers for pharmaceutical drugs, especially of mammalian compounds that require post-synthesis modifications in the cell.

- **Fish**

  Triploid salmon produced by heat shock for use as game fish in lakes and streams.

  Fish with enhanced growth rates, cold tolerance, or disease resistance for use in aquaculture.

  Triploid grass carp for use as aquatic weed control agents.

SOURCE: Office of Technology Assessment, 1988.

Impacts of Biotechnology
Unit 3

Teacher Supplement 3—Lou Harris 1986 Survey Poll About Biotechnology

Note: This is a summary of a 1986 poll conducted by Louis Harris and Associates, commissioned by the Congressional Office of Technology Assessment. 1273 American adults were polled.

1. 47% consider themselves to be interested and aware of scientific achievement.
2. 62% feel that the benefits from scientific innovation outweigh the risks.
3. 28% feel the risks outweigh the benefits.
4. 19% have heard about dangers of genetically engineered products.
5. 52% believe that genetically engineered products are somewhat likely to represent a serious danger to people or the environment.
6. 26% believe we should not meddle with nature.
7. 55% would approve environmental used of an organism that would significantly increase farm production if the risk of losing some local species of plants or fish were 1 in 1,000.
8. 78% would be willing to undergo therapy to have genes corrected if tests showed they were likely to get a serious genetic disease in life.
9. 82% believe that research in genetic engineering and biotechnology should be continued.
10. 68% of the American public feels that creating hybrid plants and animals through direct manipulation of DNA is not morally wrong.

SOURCE: *New Developments in Biotechnology 2: Background Paper, Public Perceptions of Biotechnology.* Washington, DC: Office of Technology Assessment, 1987.

Impacts of Biotechnology
Unit 3

Teacher Supplement 4—Sample Questions for Public Opinion Survey of Biotechnology

1. Rate your basic understanding of science and technology.

   (very good) 1 2 3 4 5 (poor)

2. How well do you understand genetic engineering?

   (very well) 1 2 3 4 5 (very poor)

3. Would you approve of the use of genetically engineered organisms or plants in your community?

   (approve) 1 2 3 4 5 (disapprove)

4. Do you believe that changing the genetic makeup of plants and animals is morally acceptable?

   (acceptable) 1 2 3 4 5 (unacceptable)

5. Do you believe that changing the genetic makeup of humans is morally acceptable?

   (acceptable) 1 2 3 4 5 (unacceptable)

6. Do you believe that genetically engineered products will represent a serious danger to people or the environment?

   (grave danger) 1 2 3 4 5 (no danger)

7. Would you approve of the use of a genetically engineered organism which would significantly increase farm production with no direct risk to humans?

   (approve) 1 2 3 4 5 (disapprove)

8. Would you approve of the use of genetic engineering to correct a genetic defect in your child?

   (approve) 1 2 3 4 5 (disapprove)

9. Would you approve of the use of genetic engineering to change an animal's genetic makeup and improve productive ability?

   (approve) 1 2 3 4 5 (disapprove)

Teacher Supplement 4

10. Would you approve of the use of genetic engineering to change a human's genetic makeup to increase natural intelligence?

    (approve) 1 2 3 4 5 (disapprove)

Impacts of Biotechnology
Unit 3

Information Sheet

1. **Terms and definitions**

    a. **Biological** — A medical product derived from living sources, usually referring to a vaccine

    b. **Biosensor** — A device used to detect a chemical, biological, or physical change that has a living system as one component of the device

    c. **Diagnostic** — An agent used to detect disease

    d. **Ecology** — The branch of science concerned with the interrelationships of organisms and their environments

    e. **Ecosystem** — The complex of a community and its environment functioning as a unit in nature

    f. **Environment** — The complex of climatic, soil, and life systems that acts on an organism or an ecological community and ultimately determines its form and survival

    g. **Ethics/Morals** — Principles of conduct governing an individual or a group about what is right or wrong

    h. **Pesticide** — General term for any agent used to kill undesirable organisms

    i. **Pharmaceutical** — Substance that has a medically useful effect

    j. **Probability** — Mathematical calculation of the chance that a given event will occur

    k. **Reagent** — A substance used to aid in detecting, measuring, preparing, or developing a product

    l. **Resistant** — Ability to withstand unfavorable environmental conditions

    m. **Susceptible** — Subject to the effect of a toxic or disease-producing agent

    n. **Therapeutic** — Relating to the treatment of disease or disorders by remedial agents or methods

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Information Sheet

2. Benefits of biotechnology

a. Benefits to plant science

- Rapid development of new varieties

  Note: Biotechnology requires about five generations instead of fourteen generations using traditional plant breeding.

- Addition of new capabilities to existing plants such as drought tolerance or insect and disease resistance
- Improvement of nutritional quality of plant materials
- Development of herbicide-resistant crop plants
- New methods to eliminate or reduce environmental effects of hazardous compounds
- Improved nitrogen-fixation ability and reduction in commercial fertilizer application
- Increased frost resistance

b. Benefits to animals and humans

- Development of specific vaccines for diseases such as calf diarrhea and hoof and mouth disease
- Development of specific diagnostic tests such as monoclonal antibodies for drug testing
- Alteration of gene action to control some heritable disease tendencies such as cancer
- New sources of useful products such as insulin produced by engineered bacteria
- Production of scarce materials such as the anti-viral compound interferon
- "DNA fingerprinting" for identification and paternity concerns
- Hormone therapy such as bovine somatotropin (BST) for increased milk production in dairy cattle
- Animal selection based on genetic indicators
- Production of identical offspring using embryo splitting and transfer

Information Sheet

3. **Concerns about biotechnology**

   a. Release of organisms that could harm the environment

   b. Escape of undesirable organisms from experimental studies

   c. Development of dominant organisms that overwhelm desirable organisms

   d. Development of resistant organisms that become difficult to control in the environment

   e. Loss of large genetic base (pool) by removing genes through genetic engineering

   f. Identification of genetic defects that may be used to discriminate against individuals in job selection or acceptance for insurance

   g. Genetic alteration that may cause deformities or death

4. **Environmental impacts of biotechnology**

   a. Genetically engineered organisms have the potential to affect ecosystems in undetermined and possibly detrimental ways.

   b. Many introduced species have caused harm to the ecosystem.

   Examples:

   - Dutch Elm Disease is an introduced fungus that is destroying many of America's elm trees.
   - The gypsy moth is an introduced insect pest that causes extensive damage to a wide variety of plants.
   - Kudzu is an introduced soil-erosion plant that is very invasive and has caused large scale problems.
   - Starlings are an introduced species of birds that have become pests.

   c. Many of our beneficial crop species such as soybeans, wheat, and rice were also introduced from other continents. Almost all livestock and poultry breeds are from foreign stock.

Information Sheet

d. Environmental risk factors for genetically engineered organisms

- Can the organism be contained without environmental release?
- Will the organism survive if released?
- Will it reproduce in the environment?
- Is it capable of moving to another area where it may have an unanticipated effect?
- What is the nature of the effect an organism will have in the environment?

e. Transfer of genetic information from engineered species to native species by sexual reproduction or other means (plasmids) could cause a problem.

Example: Transfer of herbicide-resistant genes from a crop plant to a weed could cause a problem with weed control.

f. The probability of harmful effect from environmental release of genetically engineered organisms is low but not zero.

g. Potential consequences of a problem in environmental release could be very significant.

h. Research into the interactions of organisms with their surroundings is key to limiting problems with environmental release.

i. The Recombinant DNA Advisory Committee (RAC) of the National Institute of Health (NIH) makes recommendations and establishes guidelines for environmental release of engineered organisms. These are binding only for federally-funded research but are generally also followed by private industry.

j. After reviewing potential ecological impacts from release of genetically engineered organisms to the environment, the Congressional Office of Technology Assessment concludes that "there is some reason to be cautious, but no cause for alarm at the prospect of environmental release."

5. **Regulatory control of biotechnology research and industry**

a. **Regulatory agencies**

- **Recombinant DNA Advisory Committee (RAC)** of the National Institute of Health (NIH)—Establishes guidelines for federally-funded research
- **Food and Drug Administration (FDA)**—Controls release and use of human and animal medical products and food additives

Information Sheet

- **United States Department of Agriculture (USDA)**—Regulates some animal and plant products and pests
- **Environmental Protection Agency (EPA)**—Controls use of pesticides, chemicals, and microorganisms with environmental effects
- **United States Congress**—Enacts laws to regulate all aspects of biotechnology
- **State and local governments**—Can impose other regulations within their jurisdiction

b. **Product protection laws**

- **Patent laws**--Provide 17 year exclusive rights for manufacture, use, and sale of a product or process
- **Trade secrecy laws**--Provide legal recourse against unauthorized use of a protected product or process

6. **Ethical issues impacting biotechnology**

a. Is biotechnology a legitimate science, or are we "playing God?"

b. Will biotechnology help relieve hunger and poverty, or will it help only the rich?

c. Is this technology useful for countries that do not raise enough food to feed themselves?

d. Will biotechnology cause more environmental problems, or will it help relieve them?

e. Will focus of biotechnology research be toward commercial profitability or relief of human suffering? Can it be both?

f. Will this technology be controlled by large conglomerates or through public representation?

g. Will biotechnology benefit large production enterprises alone, or will small units be able to benefit as well?

h. Is regulation sufficient to prevent disastrous problems from arising?

i. Is this science too complicated for reasonable use at the production level?

j. Is international structure sufficient to assure equitable access to this technology?

Information Sheet

k. Will trade barriers prevent fair market access?

l. Are biotechnologies compatible with good conservation practices?

m. Do patent and secrecy laws give excessive control of living processes?

n. Will university-industry research agreements direct research away from public good and toward the most profitable alternatives?

o. Will biotechnology narrow genetic pools and reduce genetic diversity?

p. Should we adopt high production technologies in the face of surplus commodities?

q. Do we have the right to manipulate human genes?

r. Is genetic manipulation to correct human genetic disease acceptable?

s. Is recombining genes to develop a "super" animal or human legitimate?

t. Is somatic cell (not passed on to the next generation) gene manipulation acceptable for animals? for humans?

u. Is gamete or reproductive cell gene manipulation acceptable for animals? for humans?

v. Should we compensate people who have been adversely affected by biotechnology changes?

7. **Types of companies in the biotechnology industry**

a. **Dedicated biotechnology companies**—Smaller start-up companies that began operation after 1976 to develop specific commercial products from biotechnology research

Examples: Biotech Research, Agritech, Biotech Diagnostics, Bioproducts

b. **Large diversified companies**—Established multiproduct firms using biotechnology research to develop marketable products

Examples: Dow Chemical, Monsanto, Pioneer Hi-Bred International, Inc., 3M, Miller Brewing Company, Del Monte

Information Sheet

Table 1 — Areas of Research and Development by U.S. Biotechnology Companies				
	Dedicated Co.		Diversified Co.	
Area	No.	%	No.	%
Human Therapeutics	63	21	14	26
Diagnostics	52	18	6	11
Chemicals	20	7	11	21
Plant Agriculture	24	8	7	13
Animal Agriculture	19	6	4	8
Reagents	34	12	2	4
Waste Disposal/Treatment	3	1	1	2
Equipment	12	4	1	2
Cell Culture	5	2	1	2
Diversified	13	4	6	11
Total	296	100%	53	100%

SOURCE: Office of Technology Assessment, *New Developments in Biotechnology 4.*

8. Career opportunities in biotechnology

a. Sample work areas in agriculture

- Enzymes
- Food additives
- Animal feed supplements
- Improved and new plant varieties
- Pesticides
- Herbicides
- Vaccines
- Plant growth hormones
- Fertilizers
- Nitrogen fixation
- Diagnostic reagents
- Animal genetics

Information Sheet

b. Related work areas

- Quality control
- Clinical research
- Regulatory affairs
- Manufacturing
- Production
- Information systems
- Marketing
- Sales
- Administration

9. **Positions, salary ranges, and educational requirements for careers in biotechnology**

Position	Salary Range (Annual)	Educational Requirement
Lab Assistant	$14,000 - 22,000	Associate or B.S.
Research Assistant	$22,000 - 28,000	B.S. or M.S.
Scientist	$35,000 - 51,000	PhD
Scientific Director	$38,000 - 43,000	PhD + Experience
Project Manager	$45,000 - 80,000	PhD + Experience
Technical Service Director	$45,000 - 80,000	B.S., M.S.
Field Consultant	$50,000 - 100,000+	M.S., PhD

SOURCE: *Careers in Biotechnology* published by the Industrial Biotechnology Association, January 1990.

Impacts of Biotechnology
Unit 3

Assignment Sheet 1—Respond to Concerns About Biotechnology

Name ______________________________ Overall Rating __________

Evaluation criteria	**Rating**
Responsed to all concerns	______
Responses are logical	______
Responses are clearly stated	______
Supporting statements are valid	______

Introduction: Biotechnology advocates feel that many concerns about biotechnology are exaggerated and adequate controls are in practice to prevent most of the expressed concerns. You are to discover and develop responses to these concerns.

Directions: Formulate a response to each of the following concerns about biotechnology. State how each concern can be controlled or why each concern is likely to remain a serious problem. Where possible, support your statements with information from other sources (publications, scientists, environmentalists, etc.)

Concerns About Biotechnology

a. Release of organisms that could harm the environment

b. Escape of undesirable organisms from experimental studies

c. Development of dominant organisms that overwhelm desirable organisms

d. Development of resistant organisms that become difficult to control in the environment

e. Loss of large genetic base (pool) by removing genes through genetic engineering

f. Identification of genetic defects that may be used to discriminate against individuals in job selection or acceptance for insurance

g. Genetic alteration that may cause deformities or death

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Impacts of Biotechnology
Unit 3

Assignment Sheet 2—Conduct an Opinion Poll about Biotechnology

Name ______________________________ Overall Rating __________

Evaluation criteria	**Rating**
Survey questions formulated and approved	______
Survey completed	______
Results compiled	______
Conclusions based on results	______
Conclusions are logical	______
Final report completed	______

Introduction: A great public debate about the ethics of biotechnology is certain to occur at some time in the future. A survey can give you some idea about how people in your community feel about this science at this time.

Directions: Write ten questions that you can use in conducting an opinion poll about biotechnology. Review questions in the information sheet, and discuss with your instructor other questions that would be appropriate. List those questions below, and have your instructor approve them before beginning your poll.

Now survey at least ten people in your community, and compile their responses to your questions about biotechnology.

Summarize the results, and write your conclusions about public opinions on biotechnology based on your survey.

Prepare a final report showing survey, compilations, and conclusions for evaluation.

Survey Questions

1. ______________________________

2. ______________________________

3. ______________________________

4. ______________________________

5. ______________________________

6. ______________________________

Assignment Sheet 2

7. ____

8. ____

9. ____

10 ____

Approved By ______________________
(Instructor's Signature)

Impacts of Biotechnology
Unit 3

Assignment Sheet 3—Write a Position Paper on the Ethics of Biotechnology

Name ______________________________ Overall Rating __________

Evaluation criteria	**Rating**
Paper completed	______
Paper well organized	______
Issues addressed	______
Acceptable experiments shown	______
Unacceptable experiments shown	______
Statement of personal beliefs in conclusion	______

Introduction: Position papers are used by governments, organizations, or individuals when they want to clearly state their position on a particular issue. After studying this unit, researching written statements, and seeking opinion from others, you should be able to arrive at your own position.

Directions: State your position on the ethics of genetic manipulation in plants, animals, and humans. Tell what experiments you consider acceptable and which are not acceptable. Conclude your position paper by stating your beliefs about this issue.

Impacts of Biotechnology
Unit 3

Laboratory Sheet 1—Evaluate Salt Concentration as an Environmental Factor Affecting Plant Growth

Name ______________________________ Overall Rating __________

Evaluation criteria	**Rating**
Good experimental design	______
Laboratory notebook maintained	______
Soil mixture correctly formulated	______
Plants properly maintained	______
Good observation technique used	______
Data and conclusions correct	______
Laboratory report completed	______

Introduction: Environmental factors can have a dramatic effect on plant growth. Changes brought about by biotechnology may alter environmental effects. Salt concentration in soil is one factor that can have a measurable effect on plant growth. This will be tested in this experiment.

A. Materials:

Approximately 5 lbs. potting soil
36 3-oz. paper cups
Masking tape or plastic plant markers
30 ml (1 oz.) table salt
100 ml graduated cylinder
500 ml beaker
Water tray
72 viable seeds

B. Procedure: Follow the checklist to develop your experiment. Maintain a record in your laboratory notebook and complete a laboratory report.

☐ 1. Make opening entries in your laboratory notebook.

☐ 2. Use a sharp pencil to punch 3-4 holes in the bottoms of all 36 cups.

☐ 3. Put 60 ml of soil in each of 4 cups. Label them as controls and include your initials and date. Use masking tape or plastic plant markers for ID.

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Laboratory Sheet 1

☐ 4. Mix 480 ml potting soil with 30 ml salt to obtain a 6% salt-soil mix. Put 60 ml of 6% mix in each of 4 cups and label. Save 240 ml of the salt-soil mix for the next step. Discard any excess.

☐ 5. Mix 240 ml of 6% salt-soil with 240 ml of potting soil to obtain a 3% mix. Put 60 ml of 3% mix in each of 4 cups and label. Use remaining 240 ml in next step.

☐ 6. Repeat same process for 1.5% salt-soil mix. Fill 4 cups and use remaining 240 ml for next step.

☐ 7. Repeat same process for 0.75% salt-soil mix. Fill 4 cups and use remaining 240 ml for next step.

☐ 8. Repeat same process for 0.375% salt-soil mix. Fill 4 cups and use remaining 240 ml for next step.

☐ 9. Repeat same process for 0.187% salt-soil mix. Fill 4 cups and use remaining 240 ml for next step.

☐ 10. Repeat same process for 0.094% salt-soil mix. Fill 4 cups and use remaining 240 ml for next step.

☐ 11. Repeat same process for 0.047% salt-soil mix. Fill 4 cups and use remaining 240 ml for next step.

☐ 12. Plant 2 seeds in each cup and water until soil is moist. Do not overwater or you will wash out salt. Water as needed during the experiment using the same quantity of water for each cup.

☐ 13. Place plants under light stand or in greenhouse (16 hours of light, 8 hours of dark).

☐ 14. Record observations in your laboratory notebook.

☐ 15. After the seeds germinate and emerge, remove any extra plants. (Grow only one plant per cup.)

☐ 16. Record growth pattern by measuring from soil surface to tip of plant every week. Record your measurements. Record any other observations about the plants.

☐ 17. After 6 weeks, compile your results and make your conclusions.

☐ 18. Write a complete laboratory report and turn it in for evaluation.

Biotechnology in Plant Science
Unit 4

Objective Sheet

Unit Objective

After completing this unit, the student should be able to explain the processes and applications of biotechnology in plant science. The student should be able to demonstrate these competencies by completing the assignment sheet, job sheets, and laboratory sheets and by scoring a minimum of 85 percent on the written test.

Specific Objectives

After completing this unit, the student should be able to:

1. Match terms related to biotechnology in plant science with the correct definitions.
2. Select purposes of plant biotechnology.
3. Distinguish between traditional plant breeding and genetic engineering of plants.
4. Select requirements for laboratory plant culture.
5. Complete statements concerning micropropagation and tissue culture.
6. Describe agricultural applications of plant culture.
7. Complete statements about impacts of laboratory research on production agriculture.
8. Design a plant culture facility for commercial use. (Assignment Sheet 1)
9. Construct a still air chamber from a cardboard box. (Job Sheet 1)
10. Build a light stand for plant culture. (Job Sheet 2)
11. Demonstrate cytoplasmic inheritance of leaf variegation. (Laboratory Sheet 1)
12. Demonstrate micropropagation of dry bean shoot tips. (Laboratory Sheet 2)
13. Demonstrate tissue culture of cauliflower. (Laboratory Sheet 3)

Biotechnology in Plant Science
Unit 4

Suggested Activities

Instructional Plan

1. Read the unit carefully and plan for instruction. Study the specific objectives and develop your presentation.

2. Review teaching suggestions and plan classroom, shop, and laboratory activities.

3. Plan presentation for enrichment of exceptional students as well as accommodation of special needs students.

4. Make a transparency from the transparency master included with this unit. This appears in the teacher guide only and is designed to be used with the following objective:

   TM 1—Tissue Culture (Objective 5)

5. Obtain videotapes and materials to supplement instruction of this unit. See ordering information in the Suggested Supplemental Resources section.

6. Gather materials to complete the job sheets on the light stand and still air box. These will be needed for the laboratory activities and you may want to begin work on these early in the unit. If you have an alternative design, have that ready for the laboratory activities. See the materials lists in the job sheets. Additional guidelines are given in the next section—Teaching Suggestions.

7. Decide on the laboratory activities you intend to use and order equipment and materials for these 3 to 4 weeks in advance. These laboratory activities require several weeks for completion and results. Anticipate this in setting your schedule and grading period.

8. Laboratory activity 2 will require media and materials preparation. You can prepare these in advance of the labs or design activities so the students do these. Guidelines are given in Teacher Supplement 1.

9. Provide students with the unit of instruction. Review objectives with them. Inform them about materials in the unit test.

10. Discuss the assignment sheet, job sheets, and laboratory sheets that you will use with the students. Review criteria for evaluation of these activities.

11. Discuss the use of the unit evaluation form with students. Discuss the rating scale that will be used for student evaluation.

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Suggested Activities

12. Give the written test.

13. Complete job sheet ratings, assignment sheet rating, laboratory sheet ratings, and written test scores on the unit evaluation form. Include any additional assignments.

14. Reteach and retest as required.

Teaching Suggestions

Note: Skill areas appearing in bold face type in the teaching suggestions refer to the academic and workplace skills identified by the American Society for Training and Development (ASTD) and the U.S. Department of Labor and adapted by MAVCC.

1. Obtain a video dealing with micropropagation or tissue culture. University agriculture extension offices and seed companies are good sources of materials.

2. Tissue culture is commonly practiced in many schools, industries, and by some producers. Invite someone from one of these areas to demonstrate or take a field trip to one of these facilities. Demonstrations and tours can increase the students' interest and help to reinforce **communication skills** and **group effectiveness skills**.

3. Have students develop their own narrated video as they progress through their experiments. These can be used for class activities or demonstrations and can be shown to groups, parents, school officials, etc. This can be both fun and educational. It involves **creative thinking**, **communication skills**, **self-esteem**, **interpersonal relations**, **teamwork**, and **leadership**. It also helps reinforce the importance of each step in the experiment (**science**).

4. Encourage motivated students to continue cultures at home and experiment with plant material of their own. Emphasizing self-direction helps **personal and career development** as well as **organizational effectiveness**.

5. Use a greenhouse as a source of plant material for tissue culture or as a grow out facility for regenerated plants. The regenerated plants could then be sold as a money-making class project. This activity can be used to improve **group effectiveness skills, leadership skills, math skills,** and basic free enterprise concepts.

6. Make use of the many additional kits and equipment available through biological supply companies for enrichment, individual projects, or for home use.

7. Media formulation is another activity that can be done with some additional lab equipment. Media formulation handbooks and materials are available from biological supply companies. Refer to Teacher Supplement 1 for more information on media formulation. Prepared media may be used instead if preferred.

Suggested Activities

8. Horticulture producers have used tissue culture for years in production of orchids and other plants. Contact a florist for suggestions on visiting a producer using tissue culture.

9. Encourage students to develop tissue culture and micropropagation experiments for science fair and FFA demonstrations. Encourage students with exceptional projects to apply for Agriscience Student of the Year Awards through the FFA. These projects encourage **creative thinking** and **problem solving** and help reinforce **foundation skills (science)**.

10. Although Assignment Sheet 1 occurs first in the order of the activities, it is suggested that you complete it last in this unit only. After working with plant culture experiments, the students will better understand the design needs.

11. Hold a design contest if you are developing your own culture area. Select the best design or use ideas from all designs developed in Assignment Sheet 1. This reinforces **creative thinking** and **teamwork**.

12. Refer to Teacher Supplement 2 for help in setting up a tissue culture facility at your school.

13. Guidelines for Job Sheets and Laboratory Sheets

    a. Job Sheet 1

        - Still air boxes can be purchased or built from other materials.
        - A laminar flow hood is an excellent but expensive substitute.

    b. Job Sheet 2

        - This stand works well for tissue culture.
        - Expand the width dimensions to accommodate 3 shoplights for plant culture.
        - *Wisconsin Fast Plants* materials have another design for a light stand that is adjustable.
        - Adjustable shelving that can support fluorescent fixtures can be adapted for use as a light stand.

    c. Laboratory Sheet 2

        You may want to conclude the evaluated portion of the experiment and call for the laboratory report after step 13 (as a means of shortening experimental time period).

Suggested Activities

Resources Used in Developing This Unit

1. Dodds, John H. and Lorin W. Roberts. *Experiments in Plant Tissue Culture, 2nd edition.* Cambridge, England: Cambridge University Press, 1985.
2. *Genetic Engineering: A Natural Science.* St. Louis, MO: Monsanto Company, 1985.
3. *Genetic Engineering of Plants.* National Research Council. Washington, DC: National Academy Press, 1984.
4. Kyte, Lydiane. *Plants From Test Tubes, An Introduction to Micropropagation.* Portland, OR: Timber Press, 1983.
5. McClean, Phillip. "Plant Biotechnology," prepared for *Encyclopedia of Food Science and Technology*, 1991.
6. *Of the Earth: Agriculture and the New Biology.* St. Louis, MO: Monsanto Company, 1987.

Suggested Supplemental Resources

1. *Wisconsin Fast Plants Manual*
   Carolina Plant Tissue Culture Materials Catalog
   Cabisco Biotechnology Products Catalog
   Media Formulation Booklet

   All available from:

   Carolina Biological Supply
   2700 York Road
   Burlington, North Carolina
   800-334-5551

   or

   Box 187
   Gladstone, OR 97027
   800-547-1733

2. *Sigma Chemical Company Catalog (general)* and *Sigma Cell Culture Catalog*

   Sigma Chemical Company
   P.O. Box 14508
   St. Louis, MO 63178-9916
   800-325-8070

3. *Plants From Test Tubes, An Introduction to Micropropagation* by Lydiane Kyte

   Timber Press
   P.O. Box 1613
   Beaverton, OR 97075

Suggested Activities

4. Booklet — *Food for the Future*, part of the *Biotechnology at Work* series. Available from:

   Industrial Biotechnology Association
   1625 K Street, Northwest, Suite 1100
   Washington, DC 20006
   202-857-0244

5. *The Science of Genetics: Feeding a Growing World*, 16 mm film, 26 min. Discusses plant breeding for improved hybrids and varieties. Sponsored by Pioneer Hi-Bred International, Inc.

6. *Harvest of Initiative*, VHS, 12 min. Discusses research in animal and plant science and biotechnology. Sponsored by American Cyanamid Company.

   5 and 6 are available from:

   Venard Films, Ltd.
   Box 1332
   Peoria, IL 61654
   309-699-3911

7. Slide sets and videotapes from Pioneer Hi-Bred International, Inc.

   a. *Biotechnology: Unlocking Nature's Secrets* — VHS videotape

   b. *Transforming Agriculture for the New Century* — 6 ½ minutes, VHS videotape

   c. *1990 Biotechnology: New Tools for Pioneer Plant Breeding* — Slide set and text

   d. *Quiet Revolution* — Slide set and text

   Available on free-loan basis if teachers pay return postage. Contact:

   Pioneer Hi-Bred International, Inc.
   Plant Breeding Division-Library (Helen Hoeven)
   7301 Northwest 62nd Avenue
   P.O. Box 85
   Johnston, IA 50131-0085
   515-270-3147

8. *Seeds*, 26 minutes. VHS videotape ©1987. Discusses the importance of genetic diversity and how technology has changed agriculture. Available from:

   Bullfrog Films, Inc.
   Oley, PA 19547
   800-543-FROG

Suggested Activities

Instructions For Evaluating Student Performance

Assignment Sheets — Be sure the student understands the criteria on which the evaluation is based. Assign a point value to each criterion and convert the total points to a percentage for grading.

Job and Laboratory Sheets — Rate both process and product. The process should be based on the evaluation criteria. Observe the student during the job and laboratory activities and complete the rating by assigning a point value to each criterion and converting the point total to a percentage for grading. The laboratory product should be based on the completed laboratory report.

Performance evaluation can be based on the combined process and product evaluation. A suggested performance evaluation key is given below:

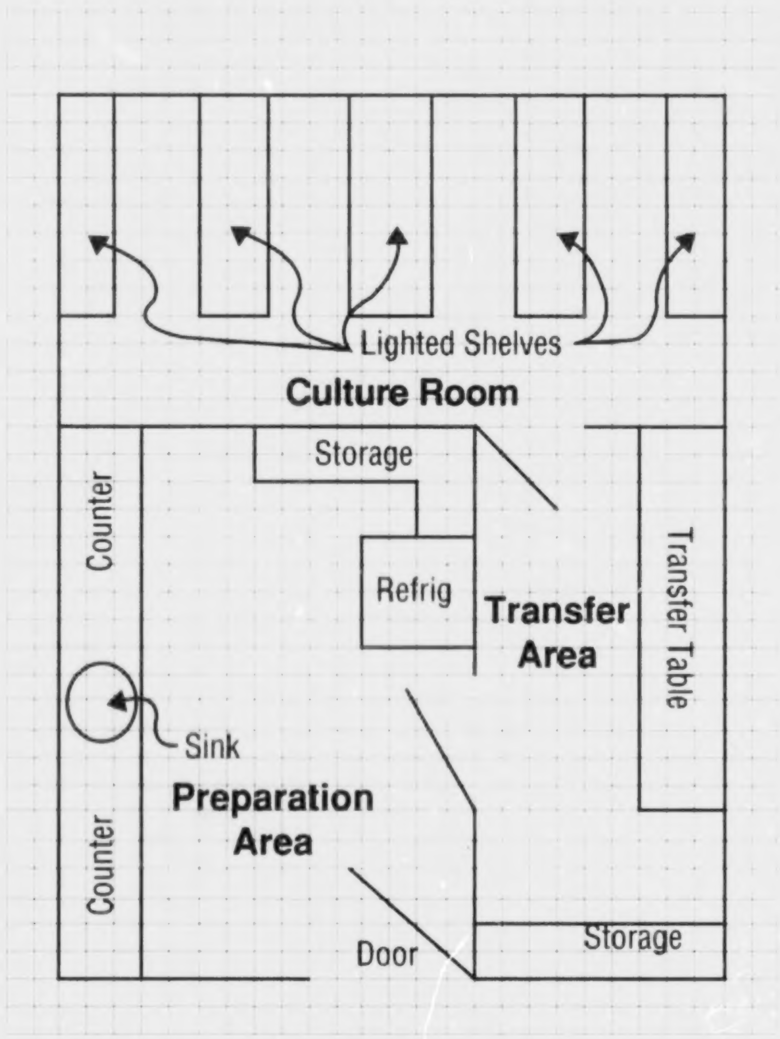
Performance level	Evaluation
90-100%	Skilled — Able to perform laboratory activity and arrive at a sound conclusion with no additional practice
80-90%	Moderately Skilled — Able to perform most laboratory activities and arrive at reasonable conclusions
70-80%	Limited Skill — Can perform some laboratory activities and work toward conclusions but needs additional practice in some areas
0-70%	Unskilled — Not able to follow procedure and reach a satisfactory conclusion; performance and evaluation must be repeated

Biotechnology in Plant Science
Unit 4

Answers to Assignment Sheet 1

Design patterns can vary considerably. The critical factors to consider are logical separation into three distinct areas: preparation, transfer, and culture. Careful consideration should be given to restricting air movement and contamination. A sample design is shown below as one example only.

Floor Plan - Tissue Culture Facility
Room Dimensions - 12 Feet By 16 Feet


Lighted Shelves
Culture Room
Storage
Counter
Refrig
Transfer Area
Transfer Table
Sink
Preparation Area
Counter
Door
Storage

Biotechnology in Plant Science
Unit 4

Answers to Written Test

1.

a.	4	m.	22
b.	8	n.	26
c.	15	o.	31
d.	7	p.	24
e.	6	q.	30
f.	2	r.	18
g.	9	s.	17
h.	12	t.	32
i.	3	u.	21
j.	1	v.	23
k.	5	w.	28
l.	14		

2. The following are marked "X" — a, b, d, f, h

3. a. GE
   b. T
   c. GE

4. The following are marked "X" — d, e, f, g, h

5. a. Test tubes
   b. Aseptic
   c. Liquid media
   d. Rapid
   e. Large

6. Descriptions will vary but should include the following points:

   a. (Glyphosate resistance)

      - Kills plants by inhibiting an enzyme that is needed for production of amino acids
      - New plants that are resistant to glyphosate have engineered versions of this enzyme that counteracts the effect of glyphosate.

Answers to Written Test

b. (Nitrogen-fixation)

- Decrease plant resistance to *Rhizobium* infection
- Increase plant production of nutrients used by N-fixing bacteria
- Develop *Rhizobium* strains that produce more usable nitrogen
- Engineer non-legume plants to accept N-fixing bacteria
- Transfer N-fixing ability to active soil organisms
- Transfer N-fixing genes from bacteria to plants

c. (Insect control)

- Apply microbes that kill insect pests to plants
- Transfer genes from insecticidal microbes to root colonizing microbes that protect plants
- Transfer genes from insecticidal microbes to plants
- Transfer genes for natural insect resistance from one plant to another

d. (Altering plants for new or improved products)

- Develop seeds with higher protein content
- Develop seeds with higher levels of essential amino acids
- Develop livestock feed with higher nutritional quality or digestibility
- Develop medicines from plants for use in treating humans and animals
- Improve milling, baking, and fermentation qualities of plants
- Develop elements of flavor

7. a. Toxic, non-toxic

b. Triazine

c. Nodule, nitrogen

d. Disease-free

e. Tobacco mosaic virus

f. Pollution

g. European corn borer

h. Microprojectile

Biotechnology in Plant Science
Unit 4

Written Test

Name ______________________________ Score ______________

1. Match the terms on the right with the correct definitions.

Note: Terms on this page match definitions on this page.

_____a. To make unfit for use by introduction of undesirable organisms

_____b. Appearance or functioning of a specific trait as a result of gene action

_____c. Actively-dividing cells at growth points on plants such as shoot and root tips

_____d. Plant part that is excised and placed in culture

_____e. To remove a piece of plant or organ

_____f. Unorganized plant tissue resulting from tissue wounding and hormone control

_____g. Complete set of chromosomes or genes present in a plant or animal

_____h. "In glass" or under laboratory or artificial conditions

_____i. A set of individuals sharing a common cell or plant origin

_____j. Absence of surface microorganisms such as fungi, bacteria, algae

_____k. Acquiring different characteristics and functions as cells become more specialized in development

_____l. Class of plants characterized by their ability to bear root nodules that contain nitrogen-fixing bacteria

1. Aseptic
2. Callus
3. Clone
4. Contaminate
5. Differentiation
6. Excise
7. Explant
8. Gene expression
9. Genome
10. Hormone
11. Hybrid
12. In vitro
13. In vivo
14. Legume
15. Meristem
16. Micropropagation

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Written Test

______m. A plant cell with the wall removed but the cell membrane intact

______n. A factor that has a detrimental effect on the normal growth and productivity of a plant

______o. A selection within a species that has identified growth and production characteristics

______p. Rapidly-growing plant tip composed of meristem and underlying tissues

______q. Refers to cells that have not developed specialized functions

______r. Ability of certain microorganisms to convert atmospheric nitrogen to forms usable by plants

______s. A cell or individual organism that differs from its parent due to a genetic change

______t. A container such as a test tube

______u. Growth of plants and plant parts from pieces of plants such as cells, tissues, organs, and protoplasts

______v. Development of an intact plant from plant parts through tissue culture

______w. Ability to develop an entire plant from the genetic information in a single cell

17. Mutant
18. Nitrogen-fixation
19. Nutrient
20. Photosynthesis
21. Plant tissue culture
22. Protoplast
23. Regeneration
24. Shoot apex
25. Somaclonal variation
26. Stress
27. Tolerance
28. Totipotent
29. Toxin
30. Undifferentiated
31. Variety
32. Vessel

2. Select purposes of plant biotechnology by placing an "X" in the appropriate blanks.

______a. Enhance nutritional quality of plant products

______b. Develop rapidly many plants from a single source

______c. Develop weeds that are resistant to herbicides

______d. Improve growth of disease-free plants ______e. Increase development time for new varieties

______f. Add new genes to plant genome

______g. Decrease amount of genes available for plant experimentation

______h. Increase plant tolerance to environmental conditions such as drought or saline soils

3. Distinguish between traditional plant breeding and genetic engineering of plants by placing a "T" next to those belonging to traditional and a "GE" next to genetic engineering.

______a. More control of outcome—Specific genes can be chosen and inserted without affecting the other genes

______b. Time consuming—Involves many generations

______c. Unconstrained crosses—Genes can be selected from any species, even outside the plant kingdom

4. Select the requirements for laboratory plant culture by placing an "X" in the appropriate blanks.

______a. Incandescent lighting placed beside the cultures

______b. Adequate amounts of circulating exterior air

______c. Lighting time of 8 hours on and 16 hours off

______d. Sterile culture containers

______e. Easily disinfected work areas

______f. Chamber with controlled air movement

______g. Access to clean water

______h. Constant temperature around room temperature

Written Test

5. Complete the following statements concerning micropropagation and tissue culture by circling the correct words.

    a. Micropropagation and tissue culture involve the growth of plants and plant parts in (production vats, test tubes).

    b. Growth must be controlled using (clean, aseptic) conditions.

    c. Growth involves a support base of (liquid media, distilled water).

    d. When growth conditions are properly controlled, growth should be (slow, rapid).

    e. Procedure can produce (small, large) numbers of identical or nearly identical offspring.

6. Write a paragraph explaining how each of these could be applied in production agriculture.

    a. Glyphosate herbicide resistance

    b. Increased efficiency of nitrogen-fixation

    c. Engineering plants for insect control

Written Test

d. Altering plants to produce new or improved products

7. Complete the statements about impacts of laboratory research on production agriculture by circling the correct words or phrases.

   a. *Bacillus thuringiensis (Bt)* is derived from bacteria and is (toxic, non-toxic) to hornworms and is (toxic, non-toxic) to humans.

   b. Canadian scientists have released (triazine, glyphosate) resistant varieties of rapeseed which are being used by producers.

   c. Testing new strains of bacteria for (nodule, gall) formation and (nitrogen, phosphorus) fixation is underway in Wisconsin.

   d. Potato producers in the Red River Valley of the North are growing tubers in tissue culture systems to provide (disease-free, virus-free) seed stock.

   e. Missouri scientists are field testing genetically altered tomatoes that are resistant to (tobacco mosaic virus, blight) infection.

   f. Plants with immune protein from animals may be used to control (animal disease, pollution).

   g. Genetically-engineered corn plants with built-in insecticides to control (European corn borer, corn earworm) are being tested in Illinois, Nebraska, Minnesota, and Maryland.

   h. Pioneer Hi-Bred is developing new strains of wheat and corn using (protoplast, microprojectile) technology to introduce new genetic material through a particle gun.

***Permission to duplicate this test is granted.**

Biotechnology in Plant Science
Unit 4

Unit Evaluation Form

Student Name ______________________________ Unit Rating __________

Assignment Sheet 1—Design a Plant Culture Facility for Commercial Use Rating ______

Comments: ____

____

Job Sheet 1—Construct a Still Air Chamber from a Cardboard Box Rating ______

Comments: ____

____

Job Sheet 2—Build a Light Stand for Plant Culture Rating ______

Comments: ____

____

Laboratory Sheet 1—Demonstrate Cytoplasmic Inheritance of Leaf Variegation Rating ______

Comments: ____

____

Laboratory Sheet 2—Demonstrate Micropropagation of Dry Bean Shoot Tips Rating ______

Comments: ____

____

Laboratory Sheet 3—Demonstrate Tissue Culture of Cauliflower Rating ______

Comments: ____

____

Unit Evaluation Form

Written Test Scores

Pretest ______ Posttest ______ Other ______

Other ____

____

Teacher Signature ______________________ Date __________

Student Signature ______________________ Date __________

***Permission to duplicate this form is granted.**

Biotechnology in Plant Science
Unit 4

Teacher Supplement 1—Guidelines for Media Required in Laboratory Sheet 2

MS media — 75 ml per student
MS5 media — 100 ml per student
B5 media — 50 ml per student

Formulation of MS media (Murashige and Skoög)

MS major and minor salts (M 5524 Sigma)
B5 vitamins (M 7150 Sigma)
3% sucrose
0.7% agar
pH 5.8

Alternatives:

(1) M 0404 Murashige and Skoög Basal Medium w/Gamborgs Vitamins (Sigma) Add sucrose and agar

(2) Murashige Minimal Organic Medium prepared and available in powder or as gel in tubes or jars (Carolina Biological)

Formulation of MS5 media

Identical to MS media except for the addition of 1.4 mg/l benzyladenine

Alternatives:

(1) M 7274 Murashige Shoot Tip Rooting Media (MS-R from Sigma) add agar

(2) Murashige Shoot Tip Rooting Media available in powder or as gel in tubes or jars (Carolina Biological)

Formulation of B5 media

B5 major and minor salts (M 5524 Sigma)
B5 vitamins (M 7150 Sigma)
2% sucrose
0.7% agar
pH 5.5

Teacher Supplement 1

Alternatives:

(1) M6899 Murashige and Skoög Basal Salts with Minimal Organics (Sigma) add sucrose and agar

(2) Gamborgs B-5 Medium, prepared and available in powder or as gel in tubes or jars (Carolina Biological)

200 ml of 40% household bleach is prepared by mixing 80 ml of liquid household bleach with 120 ml water

Biotechnology in Plant Science
Unit 4

Teacher Supplement 2—Minimum Requirements for a School Tissue Culture Facility

A. Select an area with the least possible air movement. Air vents may need to be diverted or closed.

B. Smooth wall and bench surfaces are needed to maintain cleanliness.

C. A still air chamber (Job Sheet 1) is very helpful in preventing contamination during culture procedures. Aquariums, Plexiglas boxes with portholes, or plastic laminate (Formica) lined boxes all can be adapted to work well. A laminar flow hood is an excellent but expensive substitute.

D. Access to a sink with hot and cold running water is needed for preparation of materials and hand washing.

E. A small room such as a storage room or a laboratory can be adapted to a culture facility.

F. Partitioning a corner of a classroom, shop, or greenhouse is another possibility.

G. Curtaining off an area with shower curtains or plastic can be made to work.

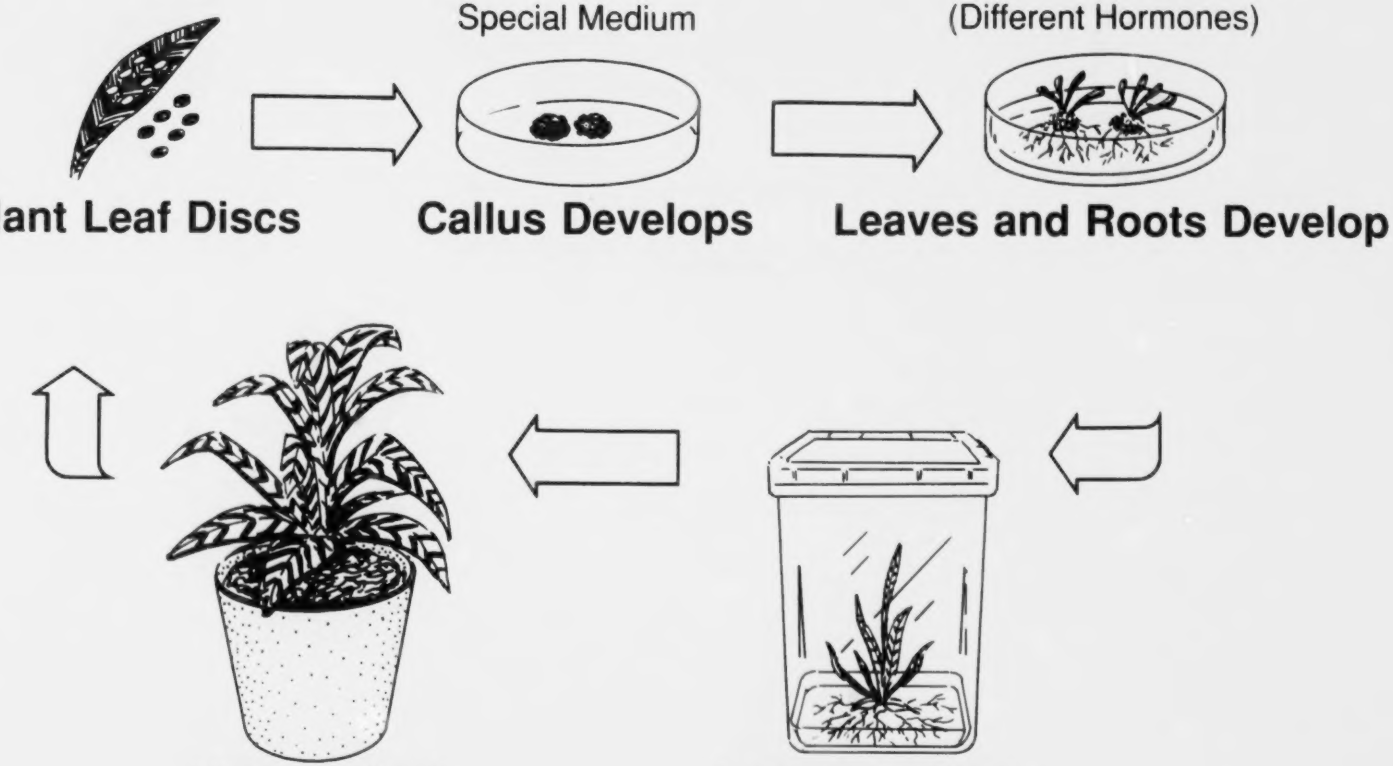
H. Sealed (parafilm) culture vessels with adequate light (fluorescent) do well most anywhere if comfortable room temperature is maintained.

I. Prepared media and culture vessels are best ordered from a biological supply company. Usually they are included in kits.

J. Instruments are often supplied with kits but minimum needs are a scalpel, blades, and forceps. Wide mouth pint or half-pint jars make good containers. A small plant misting bottle makes a good alcohol sprayer. An alcohol or bunsen burner may be needed to flame instruments.

K. Basic supplies include 80% ethanol, distilled water, household bleach, hand washing soap, and a means to sterilize water and instruments. A pressure cooker works well for the above. 30 minutes at 15 lbs pressure will sterilize instruments and smaller quantities of water.

Tissue Culture



Special Medium

Special Medium
(Different Hormones)

Plant Leaf Discs

Callus Develops

Leaves and Roots Develop

Mature Plant

Immature Plant

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Biotechnology in Plant Science
Unit 4

Information Sheet

1. **Terms and Definitions**

    a. **Aseptic** — Absence of surface microorganisms such as fungi, bacteria, or algae

    b. **Callus** — Unorganized plant tissue resulting from tissue wounding and hormone control

    c. **Clone** — A set of individuals sharing a common cell or plant origin

    d. **Contaminate** — To make unfit for use by introduction of undesirable organisms

    e. **Differentiation** — Acquiring different characteristics and functions as cells become more specialized in development

    f. **Excise** — To remove a piece of plant or organ

    g. **Explant** — Plant part that is excised and placed in culture

    h. **Gene expression** — Appearance or functioning of a specific trait as a result of gene action

    i. **Genome** — Complete set of chromosomes or genes present in a plant or animal

    j. **Hormones** — Chemical "messengers" produced by cells in one part of an organism that have a specific effect on the activities of cells remote from the point of origin

    Note: Hormones can be transferred from one organism to another and many can be isolated in the laboratory. Although hormones occur at low levels, they can have a profound effect on the organism.

    k. **Hybrid** — Offspring or cell originating from parents with differing genetic makeup

    l. **In vitro** — "In glass" or under laboratory or artificial conditions

    m. **In vivo** — "In life" or under natural or living conditions

    n. **Legume** — Class of plants characterized by their ability to bear root nodules that contain nitrogen-fixing bacteria

    Examples: Beans, peas, clover, peanuts, alfalfa

    o. **Meristem** — Actively dividing cells at growth points on plants such as shoot and root tips

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Information Sheet

p. **Micropropagation** — In vitro propagation; growth of plant shoot apex in a controlled artificial environment using culture vessels, aseptic conditions, and growth media

q. **Mutant** — A cell or individual organism that differs from its parent due to a genetic change (mutation)

r. **Nitrogen-fixation** — Ability of certain microorganisms to convert atmospheric nitrogen to forms usable by plants

s. **Nutrient** — A substance that provides nourishment for a living organism

t. **Photosynthesis** — Process of using energy from light to convert carbon dioxide (CO_2) and water (H_2O) into energy compounds usable by plants

u. **Plant tissue culture** — Growth of plants and plant parts from pieces of plants such as cells, tissues, organs, and protoplasts

v. **Protoplast** — A plant cell with the wall removed but the cell membrane intact

w. **Regeneration** — Development of an intact plant from plant parts through tissue culture

x. **Shoot apex (shoot tip)** — Rapidly growing plant tip composed of meristem and underlying tissues

y. **Somaclonal variation** — A change in a plant's characteristics as a result of mutation in somatic (non-reproductive) cells

z. **Stress** — A factor that has a detrimental effect on the normal growth and productivity of a plant

aa. **Tolerance** — The ability to grow and develop in otherwise unfavorable conditions

bb. **Totipotent** — Ability to develop an entire plant from the genetic information in a single cell

cc. **Toxin** — A poison that inhibits or stops life functions

dd. **Undifferentiated** — Refers to cells that have not developed specialized functions

ee. **Variety** — A selection within a species that has identified growth and production characteristics

ff. **Vessel** — A container such as a glass or plastic test tube, jar, or petri dish

Information Sheet

2. **Purposes of plant biotechnology**

   a. Improve crop productivity

   b. Improve plant quality

   - Enhance nutritional quality

     Example: Change the amount and kind of amino acids in seed proteins.

   - Change plant products for new uses

     Example: Develop oil products that can be used for fuels or lubricants.

   c. Improve plant performance

   - Add new genes to plant genome
   - Increase types of plants available to producers
   - Increase plant disease resistance
   - Increase plant insect resistance
   - Extend range of climate that plants can tolerate
   - Increase plant tolerance to environmental conditions such as drought or saline soils
   - Develop plants resistant to specific herbicides
   - Decrease development time for new varieties
   - Rapidly develop large numbers of plants from a single source
   - Enhance the ability of plants to use energy from photosynthesis
   - Improve growth of disease-free plants
   - Better regulate plant growth and seed production
   - Develop hybrids from sexually incompatible plants

Information Sheet

3. Comparison of traditional plant breeding and genetic engineering of plants

	Traditional Plant Breeding	Genetic Engineering of Plants
a.	**Less control of outcome** — When desired characteristics are sought, other characteristics may also appear.	**More control of outcome**—Specific genes can be chosen and inserted without affecting the other genes.
b.	**Time consuming** — Repeated back crosses are needed which involves many generations and several years.	**Saves time** — Improved varieties can be created in one generation.
c.	**Constrained by natural breeding barriers** — Only similar plants can be crossed.	**Unconstrained crosses** — Genes can be selected from any species, even outside the plant kingdom.

4. Requirements for laboratory plant culture

a. Preparation area

- Enclosed room with easily cleaned work surfaces
- Controlled air movement
- Access to clean water
- Refrigerator for storing media
- Facilities for cleaning and sterilizing instruments and equipment
- Sterile media for growth of cultures

b. Transfer area

- Chamber with controlled air movement—still air chamber or filtered air chamber
- Easily disinfected work surfaces
- Instruments to handle tissues—forceps and scalpel
- Sterile culture containers

Information Sheet

c. Culture growth area

- Constant temperature around room temperature
- Controlled lighting—fluorescent fixtures and controlled timing for lights to be on and off
- Controlled light intensity—bulbs placed above cultures
- Controlled air movement—avoid contamination from airborne particles

5. **Growing systems for plant culture**

a. Micropropagation

- Growth of plants in miniature greenhouses (test tubes, petri dishes, etc.)
- Growth under aseptic conditions

  Note: Growth of microorganisms in the same culture as plants generally kills the plant.

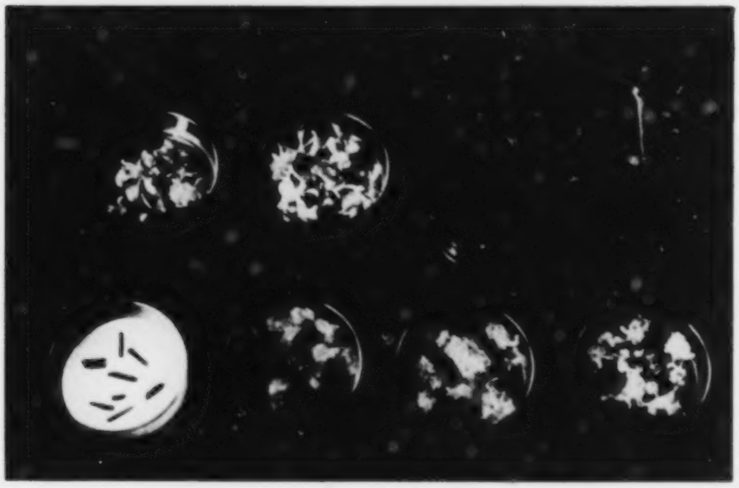
- Balanced supply of plant nutrients
- Support base of gelatin or liquid media
- Rapid growth because of controlled conditions and lack of stress
- Ease of observation
- Production of large quantities of nearly identical plants
- Production of disease-free (particularly virus-free) stock
- Selection of mutants
- Hybrid development
- Evaluation of new plant products

Information Sheet

b. Tissue culture

Note: The principles outlined for micropropagation apply to tissue culture as well. Tissue culture is a specialized form of micropropagation.

Figure 1—Tissue culture



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- Growth of cells, tissues, organs, and plant parts in culture vessels
- Based on capability to develop an entire plant from the genetic information contained in a single cell
- Usually involves converting explants to an undifferentiated state
- Involves use of plant hormones to control development
- Used by both researchers and producers
- Small amount of stock plants can produce large numbers of identical offspring (clones).
- Disease elimination in immature plants is possible with this type of culture.
- Year round growth and development are possible.
- Minimum daily care is required once culture is established.

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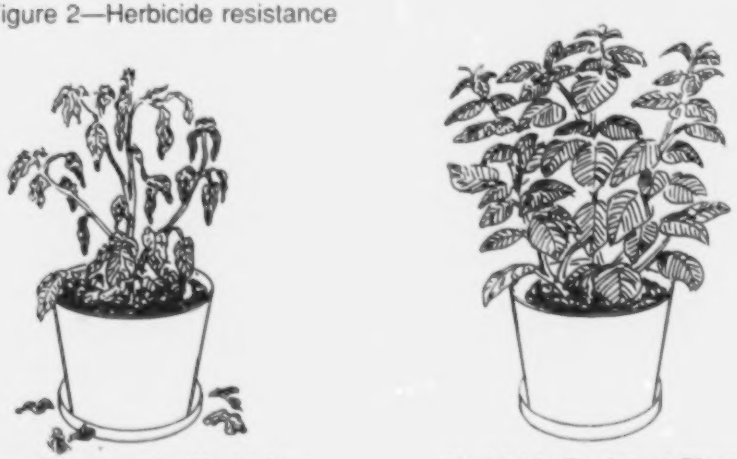
Information Sheet

6. Agricultural applications of plant biotechnology

a. Herbicide resistance—Purpose is to develop resistance in crop plants so that a herbicide can be used to eliminate all other plants in a field.

- Glyphosate (Roundup®)
  - — Kills most actively growing plants
  - — Environmentally safe because of rapid breakdown
  - — Inhibits plants from producing an enzyme needed for production of amino acids
  - — New plants that are resistant to glyphosate have engineered versions of this enzyme that counteracts the effect of glyphosate.

Figure 2—Herbicide resistance



Plant Damaged by Herbicide

Herbicide-Resistant Plant

- Triazine (Atrazine®)
  - — Most effective in killing broadleaf plants
  - — Corn and most grass plants are resistant.
  - — May have some carryover from one year to the next
  - — Several weeds have become naturally resistant to triazine.
  - — Triazine kills plants by binding in the plant cell chloroplast and blocking transport of energy from photosynthesis to other molecules.

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Information Sheet

- Resistant plants have altered binding sites that will not accept triazine so that blocking does not occur.
- Crossing resistant native plants with crop plants may produce resistant crop plants.

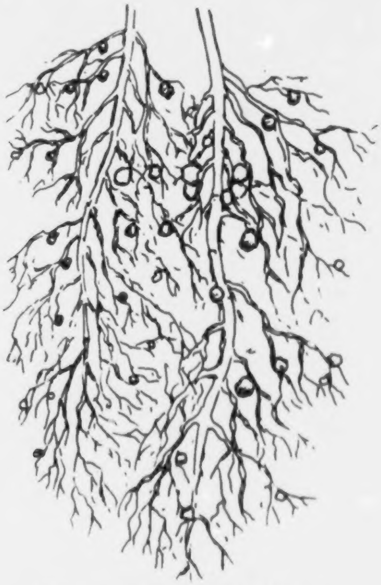
  Note: This process has been used successfully with rapeseed (canola).
- Protoplast fusion of a resistant plant with a crop plant may result in a resistant crop plant. However, other undesirable traits in the resistant plant may appear in the crop plant.
- Natural or induced mutations may result in triazine resistance in crop plants, but this is not likely.
- Transfer of the gene for triazine resistance from a resistant plant to a crop plant may be possible but is difficult to do because of gene location in the chloroplast, lack of suitable vector, and failure of gene expression.

b. Nitrogen fixation

- Nitrogen facts
  - Most important single plant nutrient
  - Rapidly depleted in cropping systems
  - Expensive to manufacture and apply as a fertilizer
  - Atmosphere is over 75% nitrogen, but this is not directly available to plants.
- Fixation process
  - Symbiotic bacteria (mainly *Rhizobium* species) infect plant roots and form nodules.
  - Plants provide nutrients for bacteria in the nodules.
  - Bacteria convert nitrogen from the atmosphere to forms usable by plants.
  - Occurs primarily in legumes.

Information Sheet

Figure 3—Nitrogen fixation



Nitrogen-Fixing Nodules

- Engineering to increase the efficiency of nitrogen fixation
  - Decrease plant resistance to *Rhizobium* infection.
  - Increase plant production of nutrients used by nitrogen-fixing bacteria in nodules.
  - Develop *Rhizobium* strains that produce more usable nitrogen.
  - Engineer non-legume plants to accept nitrogen-fixing bacteria on their roots.
  - Transfer nitrogen-fixing ability to active soil organisms such as *Azotobacter*, *Klebsiella*, or yeast organisms.
  - Transfer nitrogen-fixing genes from bacteria to plants.

  Note: These processes are difficult to do because nitrogen fixation is controlled by several genes.

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Information Sheet

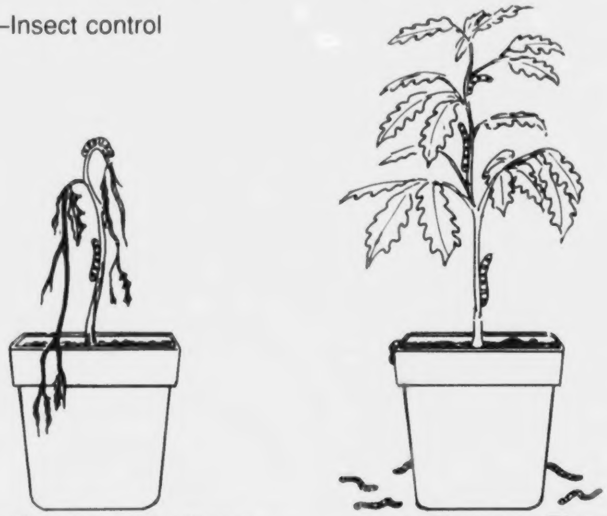
c. Engineering organisms to combat plant disease

- Some soil organisms cause plant diseases such as wilt and root rot.
- Some organisms present in the air cause plant diseases such as rust and leaf spot.
- Breeding resistant varieties has helped control some diseases but not all.
- Engineer plants directly to add genes for disease resistance.
- Engineer organisms to combat disease organisms.
  - — Organisms that compete with and displace disease organisms
  - — Organisms that produce antibiotics that inhibit disease organisms

d. Engineering for insect control

- Apply microbes with insect killing properties on plants (*Bacillus thuringiensis* or *Bt*)
- Transfer genes from insecticidal microbes to root colonizing microbes that protect plants
- Transfer genes from insecticidal microbes to plants so they can produce their own insecticide.
- Transfer genes for natural insect resistance from one plant to another

Figure 4—Insect control

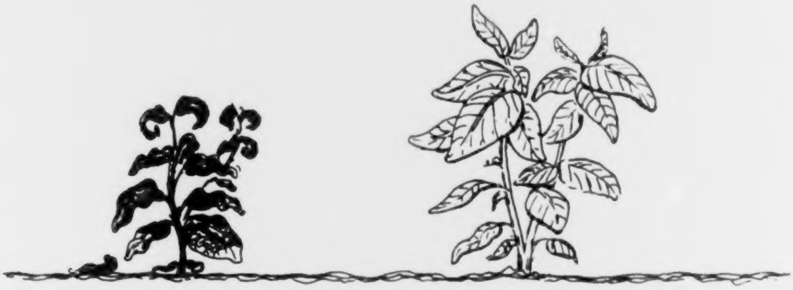


Information Sheet

e. Engineering to prevent frost damage

- Add genes from frost-resistant plants to frost-susceptible plants.
- Engineer ice-forming bacteria to remove their ice-forming capacity and apply them to plants to reduce the surface freeze point.

Figure 5—Frost resistance



Plant Damaged by Frost **Frost-Resistant Plant**

f. Engineering plants to tolerate environmental stress

- Add genes from drought-tolerant plants to crop plants.
- Add genes from plants that grow in water to crop plants raised on wet soils.
- Add genes from desert plants to crop plants to increase their heat tolerance.
- Add genes from Arctic plants to increase crop plant ability to function in cold areas.
- Add genes from salt-tolerant plants so crop plants can grow in saline soils or so crops can be irrigated with salt water.

g. Altering plants to produce new or improved products

- Develop seeds or forage with higher protein content.
- Develop seeds with higher levels of essential amino acids.
- Develop livestock feed with higher nutritional quality or digestibility.
- Develop medicines from plants for use in treating humans or animals.

- Improve milling, baking, and fermentation qualities of plants.
- Develop elements of flavor.

h. Other applications

- Regulation of plant growth and seed production
- Control of fruit ripening
- Prevention of rapid fruit deterioration
- Insertion of a specific gene for control of a plant process

Note: There are many other applications that will become practical as research continues.

7. Impacts of laboratory research on production agriculture

Note: This is a new science and the real impact on production agriculture is expected to happen in the next decade.

a. *Bacillus thuringiensis* known as *Bt* has been used for years as a garden insecticide to control hornworms and other pests. *Bt* is derived from bacteria and is non-toxic to other forms of life.

b. *Bt* gene for insecticidal protein has been transferred to some plants so they have their own insecticidal ability.

c. Glyphosate-resistant soybeans have been developed and are being field tested for release of seed.

d. Canadian scientists have released triazine-resistant varieties of rapeseed which are being used by producers.

e. Tobacco, tomatoes, and other plants have had genes introduced to make them immune to tobacco mosaic virus (TMV).

f. A California biotechnology company is testing engineered bacteria that prevent ice formation and frost damage to plants.

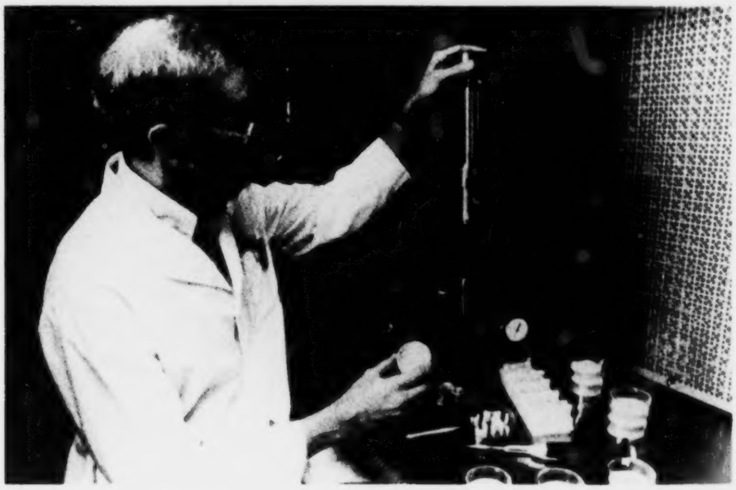
g. Testing new strains of engineered bacteria for nodule formation and nitrogen-fixation is underway in Wisconsin.

h. Monsanto has engineered a common soil microbe to produce toxins that affect insect pests that attack plant roots.

Information Sheet

i. Pioneer Hi-Bred is developing new strains of wheat and corn using microprojectile technology to introduce new genetic material through a particle gun.

Figure 6—Microprojectile bombardment using a particle gun



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j. Oklahoma scientists are working with cotton to transfer natural immunity to bacterial blight from one plant to another.

k. Potato producers in the Red River Valley of the North are growing tubers in tissue culture systems to provide disease-free seed stock.

l. Iowa scientists are developing soybean plants and bacteria that will fix nitrogen more efficiently.

m. Genes are being inserted into poplar trees to protect them from insect and disease infestation.

n. Scientists in North Dakota are developing wheat varieties that tolerate drought better than present varieties.

o. Missouri scientists are field testing genetically altered tomatoes that are resistant to tobacco mosaic virus infection.

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Information Sheet

p. A California biotechnology company is developing genetically altered tomatoes with higher usable solids for industry use.

q. Plants with immune proteins from animals may be used to control pollution, plant disease, and provide useful medical compounds.

r. Genes from oak trees that increase production of insect toxins in response to infection may be transferred to other plants.

s. Genetically-engineered corn plants with built-in insecticides to control European corn borers are being tested in Illinois, Nebraska, Minnesota, and Maryland.

t. A virus diagnostic kit has been developed to monitor the spread of viral disease in corn fields.

u. Scientists in Texas can genetically engineer potatoes to express any gene specifically in potato tubers.

Biotechnology in Plant Science
Unit 4

Assignment Sheet 1—Design a Plant Culture Facility for Commercial Use

Name ______________________________ Overall Rating __________

Evaluation criteria	**Rating**
Preparation area drawn in	______
Preparation equipment in place	______
Transfer area drawn in	______
Transfer equipment in place	______
Culture growth area drawn in	______
Lighted growth equipment in place	______
Labeling complete	______
Arrangement is logical	______
Cleanliness can be maintained	______

Introduction: Plant tissue culture facilities can be easily developed if proper air flow, cleanliness, and lighting are kept in mind. Planning a facility will give experience and ideas that can be put to practical use.

Directions: Use the attached floor plan diagram of a 12′ by 16′ room. Draw in and label all of the needed areas and basic equipment for a plant culture facility. You may add partitions if needed.

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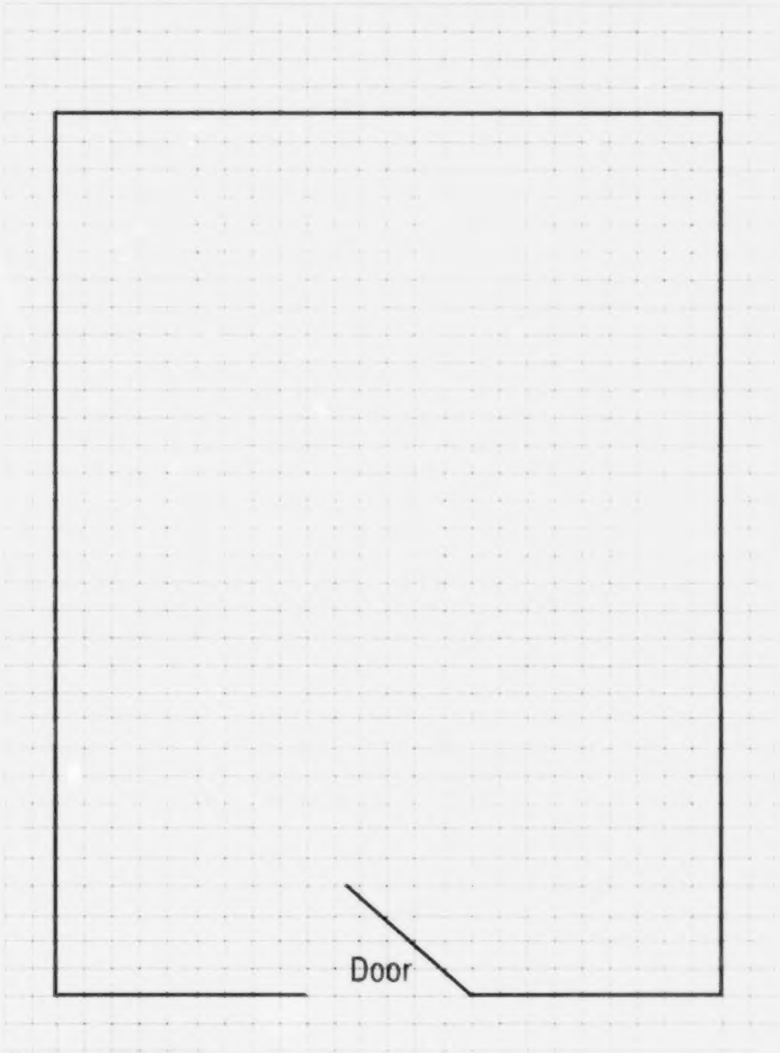
Assignment Sheet 1

Floor Plan - Tissue Culture Facility
Room Dimensions - 12 Feet By 16 Feet



Note: 2 squares = 1′

Biotechnology in Plant Science
Unit 4

Job Sheet 1—Construct a Still Air Chamber From a Cardboard Box

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation criteria	Rating
Box cutout and dimensions satisfactory	____
Foil covering of interior surface complete	____
Foil secured in position	____
Plastic front cover in proper position	____
Plastic cover secured in position	____
Work area clean	____
All items checked off checksheet	____

Introduction: Controlling the introduction of contaminants is necessary to prevent destruction of tissue culture material. A still air box is one means of reducing the possibility of contamination.

A. Materials:

Heavy cardboard box with dimensions of approximately 18″ wide, 16″ high, and 14″ deep

Heavy-duty aluminum foil 18″ wide by 8′ long

10 thumb tacks

Plastic packaging tape

Single-edge razor blade or utility knife

Sheet of clear plastic about 12″ wide by 2′ long

B. Procedure: Follow the steps to complete the still air chamber. Check off each step as it is completed.

☐ 1. Sit down at a table and position the cardboard box in front of you with the largest side facing you. Cut away this side of the box.

☐ 2. Reinforce the corners and seams with packaging tape.

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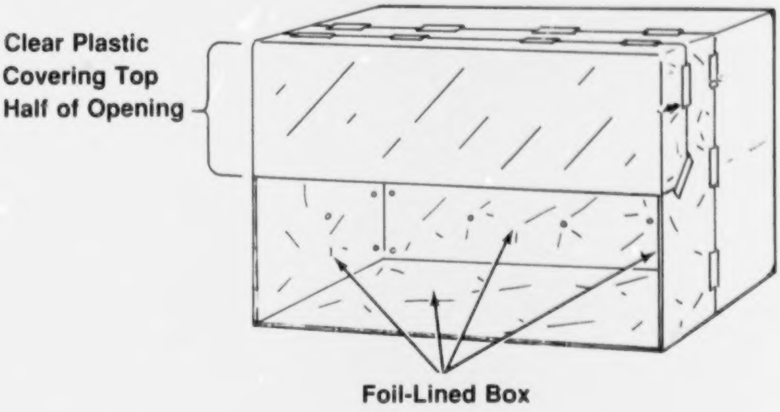
Job Sheet 1

☐ 3. Cover all interior surfaces with aluminum foil and overlap about 6″ to the outside. Lay foil up and down as well as across.

☐ 4. Tack foil to back and sides of the box as needed. Tape foil down to the exterior.

☐ 5. Reposition the box on the table in front of you with the open side toward you. Cover the top half of the opening with clear plastic and tape it in place. Leave the bottom half open.

Figure 1—Foil-lined still air box


Clear Plastic Covering Top Half of Opening
Foil-Lined Box

☐ 6. Clean up the work area and return equipment and unused materials to storage.

Evaluator's comments: ______________________________

____

____

Biotechnology in Plant Science
Unit 4

Job Sheet 2—Build a Light Stand for Plant Culture

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation criteria	**Rating**
Materials cut to correct dimensions	______
18" height from light to surface	______
Assembly solid and accurate	______
Electrical connections grounded and safe	______
Timer switch mounted properly	______
Shoplight mounting secure	______
Timer set for 16 hours on and 8 hours off	______
Clean up completed	______

Introduction: Controlled lighting is important for best growth of tissue culture materials. A simple stand using a fluorescent light fixture is a good method of providing proper lighting.

A. Equipment

claw hammer

20 8d box nails

18" x 36" — 5/8" plywood

4 — 1" x 2" boards 47" long

power saw

2 bulb 48" fluorescent shoplight

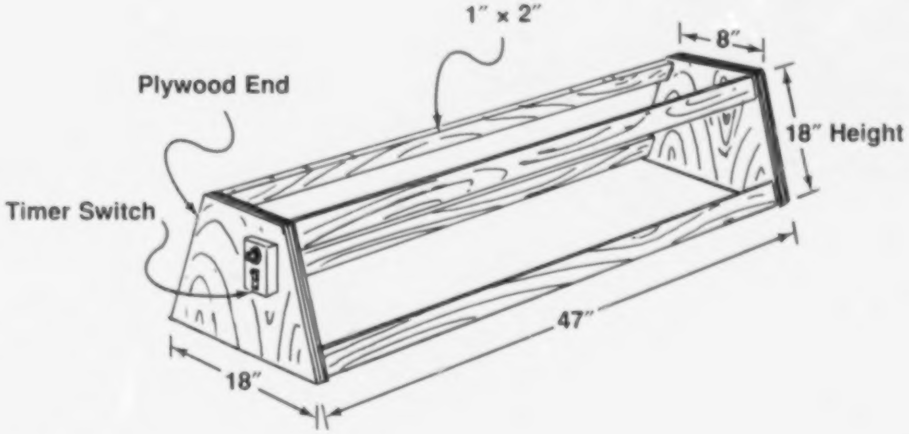
24 hour electric timer switch with one on and one off position.

Job Sheet 2

B. Procedure: Follow the steps to complete the light stand. Check off each step as it is completed.

☐ 1. Cut out the two end pieces from the plywood using the dimensions in the diagram.

Figure 1—Light Stand



☐ 2. Cut four 1" x 2" boards to 47" length.

☐ 3. Nail the 1" x 2" boards in place using the 8d box nails.

☐ 4. Support the fluorescent light fixture on top of the stand. Build any support needed to keep the fixture in place 18" above the table surface.

☐ 5. Attach the timer switch to one end of the light stand. Be sure the light cord is long enough to plug into the timer switch.

☐ 6. Set the timer for 16 hours on and 8 hours off.

☐ 7. Plug in the timer and test it by turning the timer dial and observing the light.

☐ 8. Have the instructor check your work.

Job Sheet 2

☐ 9. Your stand is ready to use for growing cultures. Clean up the area and return the tools to storage.

Evaluator's comments: ____________________

Biotechnology in Plant Science
Unit 4

Laboratory Sheet 1—Demonstrate Cytoplasmic Inheritance of Leaf Variegation

Name ______________________ Overall Rating ________

Evaluation criteria	**Rating**
Background and preparation completed	____
Pre-lab questions completed	____
Laboratory notebook maintained	
Introductory information	____
Experimental observations	____
Conclusions	____
Plant growth satisfactory	____
Discussion questions completed	____
Laboratory checklist completed	____
Laboratory report completed	____

Introduction: Plants with variegated leaves have a pattern of white markings on their leaves as opposed to solid green leaves. This is an inherited trait carried by genes in chloroplasts located in the cell cytoplasm. Growing 2 generations of plants with this genetic trait will allow you to see how variegation is expressed and the frequency with which it appears. Interestingly, triazine resistance is also a cytoplasmic gene and is presented similar to variegation.

Completion Checklist for Cytoplasmic Inheritance of Variegation

Note: *Wisconsin Fast Plants*™ Cytoplasmic Inheritance Kit # 15-8796K available from Carolina Biological Supply Company is required for this laboratory activity.

☐ 1. Refer to the kit's written materials, and review the background material, student worksheet, page 1s. Ask your instructor to explain any information you do not understand.

☐ 2. Adjust your light system so that the lights are 2" above the plants. Continuous lighting is required.

Note: The light system you built in Job Sheet 2 will need to be adjusted for this experiment. Bypass the timer because no dark period is needed. Check with your instructor for help. Place plants on a platform that can be raised and supported by bricks, blocks, or other means. An alternate light system that is adjustable may also be used.

Laboratory Sheet 1

☐ 3. Review the new terms on page 1s of the worksheet.

☐ 4. Review the objectives and obtain the materials needed to complete this laboratory activity.

☐ 5. Answer the pre-lab questions on page 2s and review these with your instructor before proceeding.

☐ 6. Record beginning information in your laboratory notebook as described in Unit 1, "Introduction to Biotechnology."

☐ 7. Read the planting and watering instructions for Rapid Cycling *Brassica*.

☐ 8. Plant the variegated plant seeds and record the planting date in your notebook.

☐ 9. Experiment day 1: 3 to 5 days after planting variegated seeds, plant the wild type seed and record the date.

☐ 10. Experiment day 4 to 5: Thin plants according to instructions on student worksheet page 3s. Record your observations.

☐ 11. Experiment day 10 to 14: Place barriers as shown on page 3s. Record observations.

☐ 12. Experiment day 14 to 18: Pollinate plants following the directions on page 4s. Record observations.

☐ 13. Experiment day 18 to 40: Continue growing plants to maturity following the "Growing Instructions." Record your observations during this time period.

☐ 14. Experiment day 45: Collect seeds from your plants following directions on page 4s. Record date and observations.

☐ 15. Plant second generation seeds and record day 1 information.

☐ 16. Count plants according to type. Follow directions on page 4s and record information in your laboratory notebook.

☐ 17. Complete discussion questions on page 5s and review these with your instructor.

☐ 18. Make your conclusions and record these in your laboratory notebook.

☐ 19. Write a laboratory report and turn it in for evaluation. Follow the laboratory report instructions in Unit 1.

Biotechnology in Plant Science
Unit 4

Laboratory Sheet 2—Demonstrate Micropropagation of Dry Bean Shoot Tips

Name ______________________ Overall Rating __________

Evaluation criteria	**Rating**
Disinfection completed	
Aseptic technique followed	
Germination accomplished	
Shoot tip excision correctly done	
Shoot tip culture successful	
Root development culture successful	
Plantlet maturation completed	
Plant grow out completed	

Introduction: Micropropagation is use of an actively growing piece of plant tissue to develop an entire plant. In this case, a small piece of actively growing stem (shoot) tissue will be used. Gelatin-like media that contains nutrients to support plant growth and hormones to stimulate development of plant structures will be used. Changing hormones and concentrations stimulate development of different plant structures as plantlets are moved to different media. Cleanliness to prevent contamination is important.

A. Materials:

8 dry bean seeds (pinto beans or seeds for green beans—garden varieties)
4 petri dishes, each containing 25 ml MS5 media
2 petri dishes, each containing 25 ml B5 media
1 half-pint wide mouth jar containing 75 ml MS media
500 ml sterile distilled water
200 ml 80% ethanol for use in a mist spray bottle
200 ml 40% household bleach (80 ml household laundry bleach and 120 ml water)

Note: Above three items have sufficient quantity for about 30 experimental set-ups.

Fine tip thumb forceps
Scalpel with #11 blade
Masking tape or parafilm
Felt tip laundry marker
Still air chamber
Fluorescent light set up for culturing material

Laboratory Sheet 2

B. Procedure: Follow the steps and check each as you complete it.

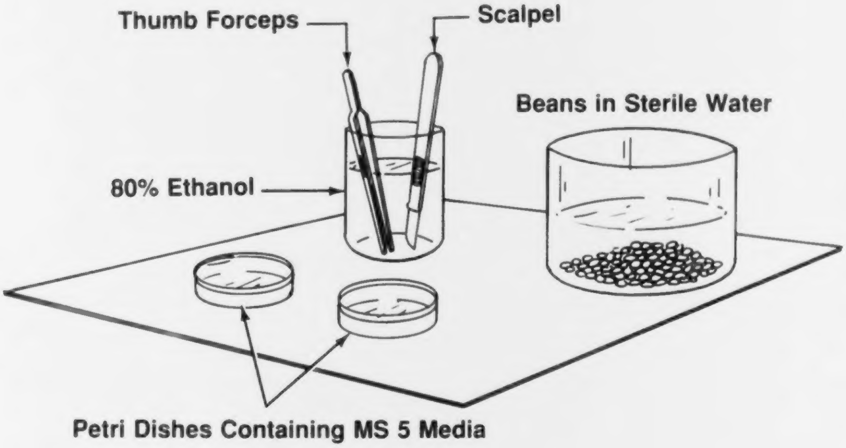
☐ 1. Complete beginning entries in your laboratory notebook.

☐ 2. Disinfect your seed by soaking up to 200 seeds in 200 ml of 40% household bleach for 5 minutes.

☐ 3. Pour off the household bleach and rinse the seeds 3 times using sterile distilled water.

☐ 4. Set up the still air box and spray down the interior with 80% ethanol and allow it to air dry. Place equipment and materials inside the box as shown in Figure 1. Spray each with ethanol as you put it in the box.

Figure 1 — Equipment Set Up For Bean Germination



☐ 5. Transfer the beans directly from the sterile water rinse and place 4 on the media in each of 2 petri dishes. Label the dish with the date, your name, bean germination, and MS 5 media. Seal the petri dishes with tape or parafilm.

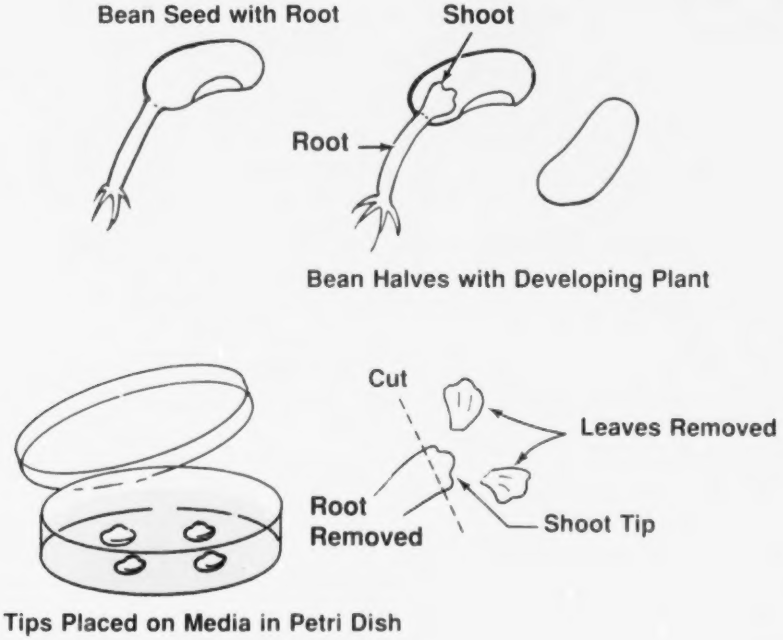
☐ 6. Germinate the seeds for 7 days under the culture lights or until the emerging root is about ½″ long. Discard seeds that are contaminated. Record observations in the laboratory notebook.

☐ 7. Set up and disinfect the still air box and equipment as in step 4. Include the germinated bean dishes and two petri dishes with MS 5 media.

Laboratory Sheet 2

☐ 8. Dissect out the shoot tip as shown in Figure 2. Use the inside of the lid of the bean germination dish as a cutting surface. Carefully place 4 tips with the cut edge down on each of the petri dishes. Seal and label your cultures.

Figure 2—Process For Dissecting Out Shoot Tip


Bean Seed with Root
Shoot
Root
Bean Halves with Developing Plant
Cut
Leaves Removed
Root Removed
Shoot Tip
Shoot Tips Placed on Media in Petri Dish

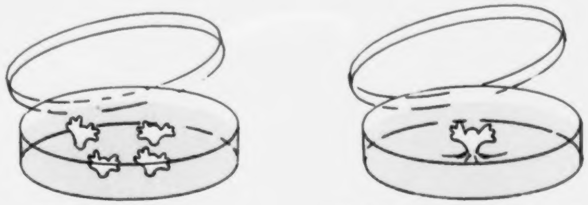
Note: Cut Edge Placed Firmly On Media.

☐ 9. Place the shoot tip culture under the grow lights for two weeks or until two leaves are developed and expanded to about ¼ inch. Record observations.

Laboratory Sheet 2

☐ 10. Prepare the work area for transferring the shoots to B5 media for root development. Select the most vigorous shoot for transfer and cut it as near the base as possible. Transfer the shoot to the center of the B5 dish placing the cut surface firmly on the media.

Figure 3—Transferring Shoots



Shoot Tip Culture **B5 Rooting Media in Petri Dish**

☐ 11. Seal and label the petri dish and culture under the grow lights for 1 week or until roots start developing. Record observations.

☐ 12. Mature the plantlet by transferring it to the media in the widemouth jar. Transfer the entire plantlet and place the root securely on the media surface. Seal and label the jar.

☐ 13. Culture the plantlets under the grow lights for about 3 weeks or until they reach 1 to 1½″ in height. Record observations.

☐ 14. Transfer the plantlets to sterile potting soil. Use clean procedure but not aseptic technique. Remove the agar and plant from the jar and gently work the agar off the roots by careful massage in warm water. Pot each plant in a 6″ pot or 2 quart milk carton base. Keep the soil moist using ½ strength liquid plant fertilizer. Keep plants in a box and cover with clear plastic to prevent excessive moisture loss.

☐ 15. After three days begin removing the plastic by opening a small section and enlarging it over several days until all is removed.

☐ 16. Grow plant to maturity under greenhouse conditions.

☐ 17. Record your conclusions in your laboratory notebook.

☐ 18. Write a laboratory report and turn it in for evaluation.

Biotechnology in Plant Science
Unit 4

Laboratory Sheet 3—Demonstrate Tissue Culture of Cauliflower

Name ____________________ Overall Rating __________

Evaluation criteria	**Rating**
Work and growth areas set up properly	______
Aseptic technique followed	______
Explant culture developed	______
Shoot initiation successful	______
Root development successful	______
Soil transplant successful	______
Checklist completed	______
Laboratory notebook maintained	______
Laboratory report completed	______

Introduction: Tissue culture is the process of developing undifferentiated tissue (callus) from a plant part followed by development of nearly identical plants (clones) from the callus. This process depends on nutrient support and hormone treatment for the various stages of development. This technology is practiced commercially as well as for research activities. Applications of tissue culture have potential in horticulture, floriculture, and crop systems.

Directions: Follow the procedures in the cauliflower tissue culture kit manual. Check each step off on the checklist as you complete it.

Note: Cauliflower Tissue Culture Kit available from Carolina Biological Supply Company is required. Similar kits may be substituted.

Completion Checklist for Cauliflower Tissue Culture

☐ 1. Set up the work area with a still air box or laminar flow hood. See Job Sheet 1.

☐ 2. Set up culture growth area with controlled lighting. See Job Sheet 2.

☐ 3. Review aseptic technique from Unit 1, "Introduction to Biotechnology."

☐ 4. Obtain the materials and equipment you need from the instructor. Review the function and use of all items with your instructor.

☐ 5. Record the introductory information and purpose for this activity in your laboratory notebook.

Laboratory Sheet 3

☐ 6. Prepare explants or obtain them from the instructor after completing the non-sterile procedures on page 4 of the *Cauliflower Tissue Culture Kit Manual.*

☐ 7. Complete the sterile procedures on pages 4 and 5 of the manual.

☐ 8. Grow cultures for 1 to 2 weeks in the growth area. Record observations in the laboratory notebook.

☐ 9. Transfer plant material to shoot initiation media following the subculturing procedure on page 5.

☐ 10. Record observations during the shoot development stage.

☐ 11. After 4 weeks, transfer shoots to a rooting medium following the procedure on page 5 of the manual.

☐ 12. Record observations during the rooting stage.

☐ 13. After roots are well developed, transfer the plantlets to soil following the transplanting procedure on page 6.

☐ 14. After acclimatizing the plants, they can be grown to maturity in a greenhouse or transplanted outdoors.

☐ 15. Record all observations during the acclimatizing and transplant phase. Complete your conclusions in the laboratory notebook.

☐ 16. Write a laboratory report and turn it in for evaluation.

Biotechnology in Animal Science
Unit 5

Objective Sheet

Unit Objective

After completing this unit, the student should be able to explain the purposes and applications of biotechnology in animal science. The student should be able to demonstrate these competencies by completing the assignment sheet and laboratory sheets and by scoring a minimum of 85 percent on the written test.

Specific Objectives

After completing this unit, the student should be able to:

1. Match terms related to biotechnology in animal science with the correct definitions.
2. List the purposes of biotechnology in animal science.
3. Distinguish between traditional animal breeding and genetic engineering of animals.
4. List ways to use biotechnology for making change in animals and animal products.
5. Match terminology related to immunology with the correct definitions.
6. List methods of stimulating an immune response.
7. Distinguish between the types of immunity.
8. Describe monoclonal antibodies.
9. List uses for monoclonal antibodies.
10. Match technologies in animal biotechnology with the correct examples.
11. Select true statements about production applications of animal biotechnology.
12. Write opinion statements about concerns in animal biotechnology. (Assignment Sheet 1)
13. Observe antigen-antibody reactions. (Laboratory Sheet 1)
14. Evaluate semen. (Laboratory Sheet 2)

Biotechnology in Animal Science
Unit 5

Suggested Activities

Instructional Plan

1. Read the unit carefully and plan for instruction. Study the specific objectives and develop your presentation.

2. Review teaching suggestions and plan classroom and laboratory activities.

3. Plan presentation for enrichment of exceptional students as well as accommodation of special needs students.

4. Make a transparency from the transparency master included with this unit. This appears in the teacher guide only and is designed to be used with the following objective:

   TM 1—Monoclonal Antibodies (Objective 8)

5. Obtain videotapes and materials to supplement instruction of this unit. See ordering information in the "Suggested Supplemental Resources" section.

6. Decide on the laboratory activities you intend to use.

   a. Laboratory Sheet 1 will require ordering kit materials 3 to 4 weeks prior to the activity.

   b. Laboratory Sheet 2 will require locating a source of bull semen.

      - Suggested sources are: (1) an artificial insemination technician, (2) a beef or dairy producer performing artificial insemination, or (3) a veterinarian that does bull breeding soundness evaluations.

      - Fresh semen should be evaluated shortly after collection and frozen semen shortly after thawing.

7. Provide students with the unit of instruction. Review objectives with them. Inform them about materials on the unit test.

8. Discuss the laboratory sheets and the assignment sheet that you will use with the students. Review criteria for evaluation of these activities.

9. Discuss the use of the unit evaluation form with students. Discuss the rating scale that will be used for student evaluation.

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Suggested Activities

10. Give the written test.

11. Compile laboratory sheet ratings, assignment sheet rating, and written test scores on the unit evaluation form. Include any additional assignments.

12. Reteach and retest as required.

Teaching Suggestions

Note: Skill areas appearing in bold face type in the teaching suggestions refer to the academic and workplace skills identified by the American Society for Training and Development (ASTD) and the U.S. Department of Labor and adapted by MAVCC.

1. Show a video dealing with biotechnology in animal science. Use as an introduction or for added interest. See the "Suggested Supplemental Resources" section for information. Videos help reinforce **listening** skills and can serve as **motivation** for students to learn more about biotechnology.

2. Many diagnostic tests are in use that apply new technologies such as monoclonal antibodies. A medical or veterinary technician could explain and demonstrate these. This could be done as a field trip or as a classroom demonstration. Demonstrations by outside resource people can be very important in helping students learn practical applications of biotechnology (**science skills**) and can also help them identify **career goals** (**personal management skills**).

3. An artificial insemination technician could demonstrate thawing semen and the process of artificial insemination. This could be done as a field trip or partially in a classroom setting. (**Science skills** and **personal management skills**)

4. Consult local and state regulations and committee standings on animal rights. Provide students with this information, and then lead a class discussion on the impact of these regulations on education and research. Discuss the pros and cons of the regulations. This activity reinforces **communication skills** and **problem-solving**. It can also make students more aware of the government's role in biotechnology.

5. Obtain reproductive tracts of animals from slaughter plants or butcher shops. A veterinarian would be a good resource person to explain function and demonstrate techniques for A.I., infusion, tract examination, pregnancy diagnosis, embryo transplant, and so forth.

   Note: Be aware of student or public sensitivity to use of animal tissues in this manner. This activity may not be possible in your area because of regulations on animal rights.

6. Have students develop their own videos or slide series on the experiments they do. These can be used for future demonstrations or public information programs.

Suggested Activities

7. Take advantage of students' natural interest in animals. Have them develop projects experimenting with biotechnology techniques. Encourage them to use these for science fair activities, FFA demonstrations, and for awards in the FFA Agriscience Student of the Year program. These projects encourage **creative thinking** and **problem solving** and help reinforce **foundation skills (science)**.

8. Develop your own experiments and demonstrations for enrichment. Biological supply company catalogs have other kits and materials available for laboratory activities.

9. A field trip to an animal science department at a university or experiment station is worthwhile if advance preparation is done and researchers are aware of students' backgrounds. Animal biologics companies are also good possibilities. Alternatively, a classroom presentation or demonstration by an animal scientist is another approach.

10. The opinion statements from Assignment Sheet 1 make excellent starting material for class discussion or debate. You may also invite people from the community to serve as a panel for discussion of these issues and interaction with the students. This can help students see that many people in their community also have opinions about biotechnology in animal science. This activity can increase students' interest as well as outside interest in your program. Skills reinforced here include **communication skills**, **problem solving skills**, and **group effectiveness skills**.

Resources Used in Developing This Unit

1. Kieffer, George H. *Biotechnology, Genetic Engineering, And Society.* University of Illinois at Urbana-Champaign, IL: National Association of Biology Teachers, 1987.

2. *Of The Earth: Agriculture and the New Biology.* St. Louis, MO: Monsanto Company, 1987.

3. Olson, Steve. *Biotechnology: An Industry Comes of Age.* Washington, DC: National Academy Press, 1986.

4. Sattelle, David B. *Biotechnology in Perspective.* Washington, DC: Industrial Biotechnology Association, 1990.

5. *What is Biotechnology?* Washington, DC: Industrial Biotechnology Association, 1989.

Suggested Activities

Suggested Supplemental Resources

1. VHS videotapes

   a. *Connections: Animals, People, and Biotechnology.* 1989. (19 minutes) Sponsored by American Cyanamid Company.

   b. *Bovine Somatotropin Series.* (13 minutes) Includes 4 short news releases. Sponsored by American Cyanamid Company.

   c. *B.S.T., Continuing a Dairy Tradition.* (11 minutes) Sponsored by the Monsanto Company.

   Videotapes a-c are available from:

   Venard Films Ltd.
   Box 1332
   Peoria, IL 61654
   309-699-3911

2. Antibody-Antigen Kit #1: Ovalbumin (Egg Albumin)—Anti-Ovalbumin, Catalog # 2-8. Available from:

   Modern Biology, Inc.
   P.O. Box 97
   Dayton, IN 47941-0097
   800-733-6544

3. Booklets from *Biotechnology at Work Series*

   a. *Diagnostics*

   b. *Animals, People, and Biotechnology*

   Available from:

   Industrial Biotechnology Association (IBA)
   1625 K Street, Northwest
   Suite 1100
   Washington, D.C. 20006
   202-857-0244

Suggested Activities

Instructions For Evaluating Student Performance

Assignment Sheet — Be sure the student understands the criteria on which the evaluation is based. Assign a point value to each criterion and convert the total points to a percentage for grading.

Laboratory Sheets — Rate both process and product. The process should be based on the evaluation criteria for the laboratory activity. Observe the student during the laboratory activity and complete the rating by assigning a point value to each criterion and converting the point total to a percentage for grading. The laboratory product should be based on the completed laboratory report.

Performance evaluation can be based on the combined process and product evaluation. A suggested performance evaluation key is given below:

Performance level	Evaluation
90-100%	Skilled — Able to perform laboratory activity and arrive at a sound conclusion with no additional practice
80-90%	Moderately Skilled — Able to perform most laboratory activities and arrive at reasonable conclusions
70-80%	Limited Skill — Can perform some laboratory activities and work toward conclusions but needs additional practice in some areas
0-70%	Unskilled — Not able to follow procedure and reach a satisfactory conclusion; performance and evaluation must be repeated

Biotechnology in Animal Science
Unit 5

Answers to Assignment Sheet 1

Opinion statements will vary considerably. Consideration should be given to original thought, logical argument for position, and evidence of gathering background information. You may want to use this assignment for class presentation and discussion.

Biotechnology In Animal Science
Unit 5

Answers to Written Test

1.

a.	8	g.	16
b.	2	h.	3
c.	13	i.	17
d.	9	j.	6
e.	12	k.	11
f.	7		

2. Any three of the following:

   a. Increase milk, meat, egg, and fiber production
   b. Prevent and control animal disease
   c. Improve quality and composition of animal food products
   d. Produce novel products through genetic alteration of animals

3. a. GE
   b. T
   c. GE

4. Any two of the following:

   a. Alter the animal's diet
   b. Give the animals hormones or other beneficial drugs
   c. Genetically alter the animal to change their offspring and future generations

5.

a.	4	d.	5
b.	1	e.	2
c.	6	f.	7

6. Any three of the following:

   a. Contracting actual disease and building natural immunity
   b. Exposure to a very small dose by an unnatural route (smallpox on skin surface)
   c. Use of a killed organism (bacterin)
   d. Use of an altered toxin (toxoid)
   e. Live but attenuated (weakened) organism which changes the organism to remove its disease-causing ability but leaves its ability to stimulate an immune response
   f. Cross immunity—closely related organisms may stimulate immunity in an animal that is not a natural host to the disease.
   g. Genetic alteration of organisms to remove their disease-causing ability while leaving their ability to cause an immune response
   h. Subunit vaccines where only the specific protein that stimulates immunity is used which results in few side effects

Answers to Written Test

7.

a.	P	d.	P
b.	P	e.	A
c.	A	f.	A

8. Description should include: A monoclonal antibody is formed by fusing an antibody-forming cell with a cancer-producing cell. The cancer cell reproduces in culture and reproduces the attached antibody as well. After culture, extraction of many identical antibodies is possible. This gives a large amount of pure and specific antibody.

9. Any five of the following:

   a. Control specific diseases
   b. Screen for early detection of disease or cancer
   c. Locate cancer cells within the body
   d. Carry anticancer drugs to cancer cells without affecting normal cells
   e. Isolate scarce proteins such as hormones or useful medical compounds
   f. Match tissue for organ transplant
   g. Detection early pregnancy
   h. Produce anti-serum (fluid portion of blood that contains antibodies) for pre-transfusion testing
   i. Test for presence of biologics and drugs
   j. Has potential for arthritis treatment
   k. Detect pathogenic organisms in food, water, or medical products
   l. Prenatal testing for genetic counseling

10.

a.	3	e.	2
b.	5	f.	2
c.	1	g.	4
d.	3		

11. The following are marked "X" — a, c, d, e

Biotechnology in Animal Science
Unit 5

Written Test

Name ______________________________ Score ______________

1. Match the terms on the right with the correct definitions.

______a. Produced by or composed of cells derived from a single cell

______b. A short piece of DNA that will bind with DNA containing like sequences and be detected

______c. A factor that has a detrimental effect on the normal growth and productivity of an animal

______d. A substance that provides nourishment for a living organism

______e. Fluid and cells ejaculated from male reproductive organs to support living sperm

______f. A large molecule built up from smaller chemical structures

______g. Description of an individual developed through genetic engineering or gene transfer

______h. Developing individual from the time of fertilization to birth

______i. A preparation of antigenic material that stimulates an antibody response to disease-causing organisms without causing disease

______j. A chemical messenger of the immune system that inhibits viral replication and may have anticancer properties

______k. Bacteria and yeast preparations fed directly to animals to gain some benefit

1. Carrier
2. DNA probe
3. Embryo
4. Genetic marker
5. Hormones
6. Interferon
7. Macromolecule
8. Monoclonal
9. Nutrient
10. Polyclonal
11. Probiotics
12. Semen
13. Stress
14. Subunit vaccine
15. Synthesize
16. Transgenic
17. Vaccine

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Written Test

2. List three purposes of biotechnology in animal science.

   a. ____

   ____

   b. ____

   ____

   c. ____

   ____

3. Distinguish between traditional animal breeding and genetic engineering of animals by placing a "T" next to those belonging to traditional and "GE" next to genetic engineering.

   ______a. More control of outcome—Specific genes can be chosen and inserted without affecting the other genes

   ______b. Time consuming—Selection relies on production data which takes years to collect

   ______c. Unconstrained crosses—Genes can be selected from any species, even outside the animal kingdom

4. List two ways to use biotechnology for making changes in animals and animal products.

   a. ____

   ____

   b. ____

   ____

Written Test

5. Match the terminology related to immunology on the right with the correct definitions.

______a. Bodily response to an antigen that involves the formation of antibodies to render the antigen harmless

______b. Any body immunoglobulin that is produced in response to a specific antigen and that counteracts its effect

______c. Methods used to stimulate a remembered ability to respond to the agent causing the disease

______d. Ability to resist a particular disease

______e. Any foreign macromolecule that is capable of stimulating an immune response

______f. Science that deals with immunity and immune responses

1. Antibody
2. Antigen
3. Antigenicity
4. Immune response
5. Immunity
6. Immunization
7. Immunology

6. List three methods of stimulating an immune response.

a. ______________________________

b. ______________________________

c. ______________________________

7. Distinguish between the types of immunity by placing an "A" next to active immunity and a "P" next to passive immunity.

______a. Result of the transfer of antibodies from an immune source

______b. Immediate protection

______c. Stimulates long-term "memory"

______d. Short-term immunity with no "memory"

______e. Stimulated by introduction of an antigen

______f. Stimulated by vaccines

Written Test

8. Describe a monoclonal antibody. Tell how it is formed, reproduced, and what purpose this serves.

9. List five uses for monoclonal antibodies.

a. ____

b. ____

c. ____

d. ____

e. ____

10. Match the technologies in animal biotechnology with the correct examples.

______a. Bovine somatotropin (Bst) is being produced by engineered organisms and is used to increase milk production in dairy cattle.

______b. Microinjection of DNA into early embryonic cells will change the genetic makeup of the newborn.

______c. Involves collecting, transporting, and delivering semen to female at proper stage of heat cycle

______d. Growth hormones produce profound effects on growth rate, productive capacity, and the nature of the product produced.

______e. Fertilized ova can be implanted in another animal to grow until birth.

______f. In early stages, embryos can split several times to produce several identical offspring.

______g. Production of penicillin from a fungus was the first application of this technology.

1. Artificial insemination
2. Embryo manipulation
3. Hormonal technology
4. Antibiotic technology
5. Genetic engineering (direct)

Written Test

11. Select true statements about production applications of animal biotechnology by placing an "X" in the blanks of the true statements.

______a. Feed use can be enhanced by increasing amino acid levels.

______b. Interferon is a disease management tool that controls antibodies.

______c. Embryo transplant is a reproductive management tool.

______d. Monoclonal antibodies can be useful in disease management by helping identify carriers of a disease.

______e. Growth-promoting implants are a reproductive management tool.

______f. Reaching market weights at an earlier age can be introduced by genetic engineering.

______g. Monoclonal antibodies can be used for regulating growth and reproduction.

*** Permission to duplicate this test is granted.**

Biotechnology in Animal Science
Unit 5

Unit Evaluation Form

Student Name ______________________ Unit Rating __________

Assignment Sheet 1—Write Opinion Statements About Concerns in Animal Biotechnology Rating ______

Comments: ______________________________________

____

Laboratory Sheet 1—Observe Antigen-Antibody Reactions Rating ______

Comments: ______________________________________

____

Laboratory Sheet 2—Evaluate Semen Rating ______

Comments: ______________________________________

____

Written Test Scores

Pretest ______ Posttest ______ Other ______

Other ______________________________________

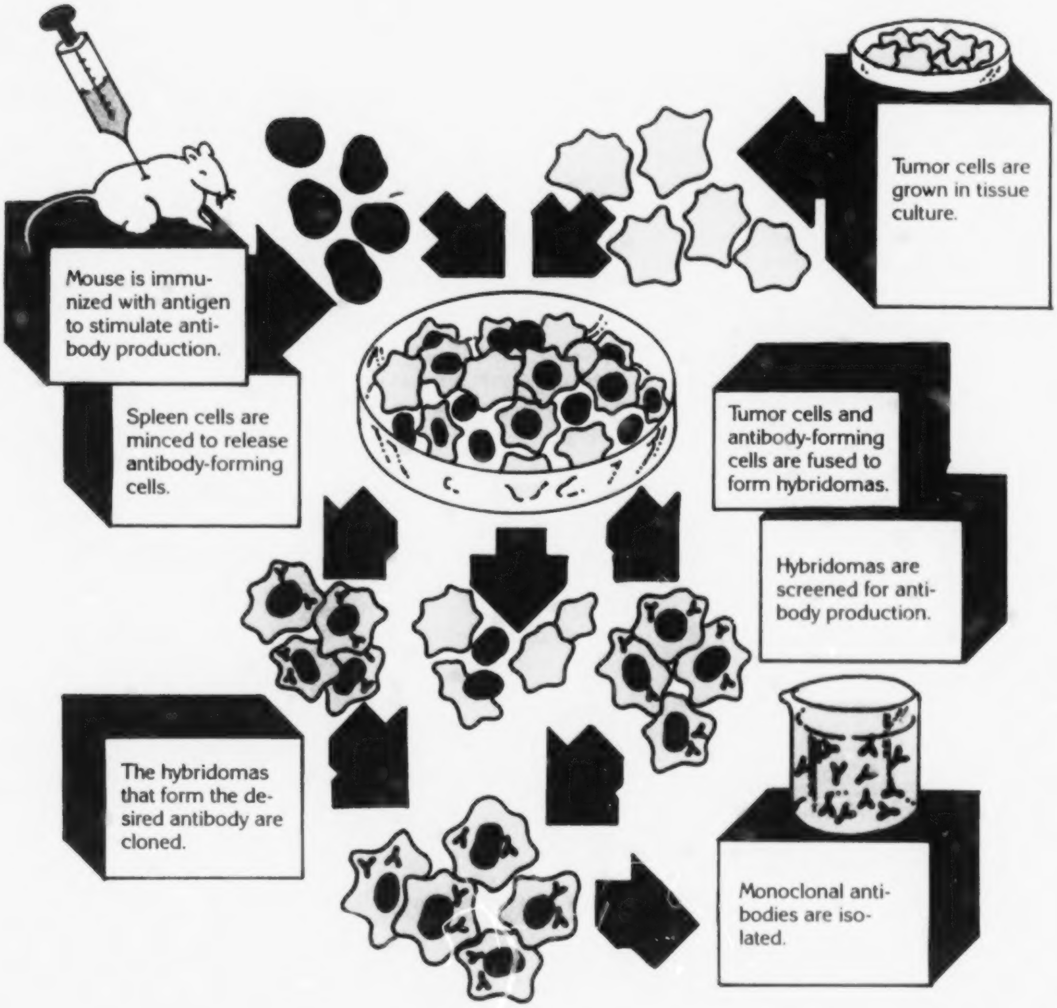
____

Teacher Signature ______________________ Date __________

Student Signature ______________________ Date __________

*Permission to duplicate this form is granted.

Monoclonal Antibody Technology


Mouse is immunized with antigen to stimulate antibody production.
Spleen cells are minced to release antibody-forming cells.
Tumor cells are grown in tissue culture.
Tumor cells and antibody-forming cells are fused to form hybridomas.
Hybridomas are screened for antibody production.
The hybridomas that form the desired antibody are cloned.
Monoclonal antibodies are isolated.

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Biotechnology in Animal Science
Unit 5

Information Sheet

1. **Terms and definitions**

   a. **Carrier** — Individual that can harbor an organism without developing the associated disease

   b. **DNA probe** — A short piece of DNA that will bind with DNA containing like sequences and be detected

   Note: By attaching a marker to the probe, a specific cell type such as cancer can be identified and located.

   c. **Embryo** — Developing individual from the time of fertilization (combining of ovum and sperm) to birth

   d. **Genetic marker** — Identifiable pieces of DNA that are located near an unidentified gene; used to show the presence and transfer of the gene from one generation to the next

   e. **Hormones** — Chemical "messengers" produced by cells in one part of an organism that have a specific effect on the activities of cells remote from the point of origin

   f. **Interferon** — A chemical messenger of the immune system that inhibits viral replication and may have anticancer properties

   g. **Macromolecule** — A large molecule (molecular weight 10^3 - 10^9) built up from smaller chemical structures (building blocks such as amino acids, simple sugars, fatty, acids, etc.)

   Examples: Proteins, polysaccharides, lipids, nucleic acids (DNA, RNA)

   h. **Monoclonal** — Produced by or composed of cells derived from a single cell

   i. **Nutrient** — A substance that provides nourishment for a living organism

   j. **Polyclonal** — Produced by or composed of cells derived from preparations containing many kinds of cells

   k. **Probiotics (direct-fed microbials)** — Bacteria and yeast preparations fed directly to animals to gain some benefit

   l. **Semen** — Fluid and cells ejaculated from male reproduction organs to support living sperm

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Information Sheet

m. **Stress** — A factor that has a detrimental effect on the normal growth and productivity of an animal

n. **Subunit vaccine** — Isolation of antigenic surface proteins from disease-causing organisms and their use as a highly purified vaccine with virtually no side effects

o. **Synthesize** — The production of a compound by putting together its component parts

p. **Transgenic** — Description of an individual developed through genetic engineering or gene transfer

q. **Vaccine** — A preparation of antigenic material that stimulates an antibody response to disease-causing organisms without causing disease

2. Purposes of biotechnology in animal science

a. **Increase milk, meat, egg, and fiber production**

Examples:

- Genetically-engineered hormones (Bst) are being used to increase the milk production of dairy cows.
- Probiotics may be used to overcome stress which is hampering production.
- Digestive bacteria may be engineered to utilize more of the feed's components.
- Multiple birth capacity may be increased in many species.

b. **Prevent and control animal disease**

Examples:

- Gene-related disorders may be treated by changing the genes responsible for the disease.
- Vaccines developed through genetic engineering for calf and pig scours and hoof and mouth disease are in use and others are in development.
- Subunit vaccines using pure antigens will provide specific disease protection with few side effects.
- Interferon is being tested for use in controlling some types of cattle shipping fever.

Information Sheet

c. **Improve quality and composition of animal food products**

Examples:

- Genetically-engineered hormones (Pst) are being used to increase muscle and decrease fat in swine production providing leaner pork for consumers.
- Researchers are using genetic engineering to lower the cholesterol count in beef products and eggs.

d. **Produce novel products through genetic alteration of animals**

Examples:

- Drugs that are very expensive to produce may be produced in cows' milk by introducing the gene into dairy cows.
- Transgenic sheep can secrete human blood factor IX in their milk.

  Note: This factor is essential for proper blood clotting and is needed by people with bleeding disorders.
- Chicken eggs may be transformed to produce drugs for animal and human use.

3. **Comparison of traditional animal breeding and genetic engineering of animals**

	Traditional Animal Breeding	Genetic Engineering of Animals
a.	**Less control of outcome** — Crosses result in many genetic changes, some of which may not be desired.	**More control of outcome** — Specific genes can be chosen and inserted without affecting the other genes.
b.	**Time consuming** — Selection relies on production data which takes years to collect.	**Save time** — Identification of specific changes is possible immediately.
c.	**Constrained by natural breeding barriers** — Reproductive compatibility is limited to related species.	**Unconstrained crosses** — Genes can be selected from any species, even outside the animal kingdom.

Information Sheet

4. **Using biotechnology for making changes in animals and animal products**

a. Alter the animal's diet

Examples:

- Bacteria can be engineered to overproduce essential amino acids (lysine, tryptophan) that are limited in cereal grains.
- Single-cell protein sources using engineered bacteria and yeast may provide all protein requirements for animals.

b. Give the animals hormones or other beneficial drugs

Examples: Bst, Pst, probiotics

Note: Methods a and b **do not genetically alter the animal**. These changes will not be passed on to the next generation.

c. Genetically alter the animal to change their offspring and future generations

Note: It will be possible in the future to change, add, or delete any gene in an animal in order to improve production. For example, instead of giving the animal growth hormone injections, it will be possible to change the animal's growth hormone gene so that larger animals are produced without the need for supplemental hormones.

5. **Terminology related to immunology**

Note: Understanding basic concepts in immunology is important since many developments in biotechnology are directly related to this science.

a. **Antigen (Ag)** — Any foreign macromolecule (usually protein or carbohydrate substance) that is capable of stimulating an immune response

Note: The body does not recognize this macromolecule as "belonging" there.

Examples: Infectious agent such as bacteria, organic material such as a wood splinter, tissue from another individual such as a transplanted organ

b. **Antigenicity** — Level of response caused by an antigen

Examples: High level response is caused by smallpox in humans or bangs disease in cattle. Low level response is caused by the common cold virus in humans or *Pasteurella pneumonia* in livestock.

Information Sheet

c. **Antibody (Ab)** — Any body immunoglobulin (serum protein) that is produced in response to a specific antigen and that counteracts its effect

  - Antibodies develop a very specific defense to each antigen.
  - Antibodies are developed by blood cells called lymphocytes and cells in the tissue spaces called plasma cells.

d. **Immune response** — Bodily response to an antigen that involves the formation of antibodies to render the antigen harmless

  - Length of memory and level of response vary with the nature of the antigen (antigenicity) and how often exposure occurs.
  - In addition to antibodies, other body cells such as T-cells and natural killer cells are activated in the immune response.

e. **Immunity** — Ability to resist a particular disease.

  - This includes a "memory system" that develops after exposure to a specific antigen.
  - A stronger and more rapid response is triggered upon a second exposure to the same antigen.

f. **Immunology** — Science that deals with immunity and immune responses

g. **Immunization** (also called vaccination, inoculation, and "shots") — Methods used to stimulate a remembered ability to respond to the agent causing the disease

  - Effectiveness of the immunity depends on the antigenicity of the agent (antigen) used
  - Boosters or repeat inoculations create a higher level of immunity and a longer immune memory.

6. **Methods of stimulating an immune response**

a. Contracting actual disease and building natural immunity

b. Exposure to a very small dose by an unnatural route (smallpox on skin surface)

c. Use of a killed organism (bacterin)

d. Use of an altered toxin (toxoid)

e. Live but attenuated (weakened) organism which changes the organism to remove its disease-causing ability but leaves its ability to stimulate an immune response

f. Cross immunity — Closely related organisms may stimulate immunity in an animal that is not a natural host to the disease.

Example: Human measles virus is closely related to canine distemper virus so human measles vaccine can be used to protect dogs against distemper.

g. Genetic alteration of organisms to remove their disease-causing ability while leaving their ability to cause an immune response

h. Subunit vaccines where only the specific protein that stimulates immunity is used which results in few side effects

7. Types of immunity

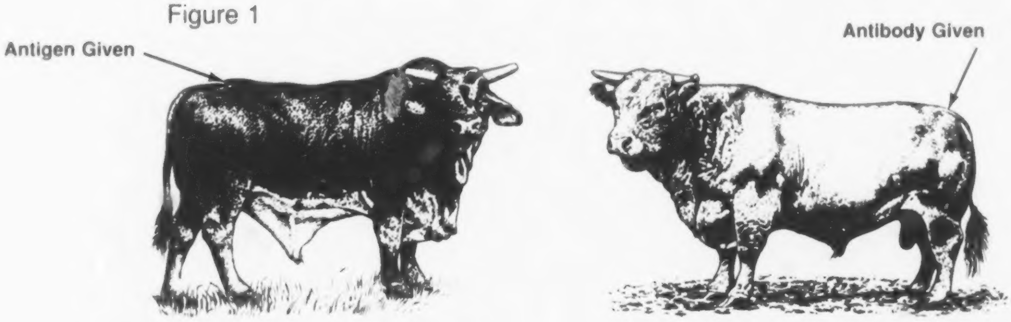
a. Active immunity

- Stimulated by introduction of an antigen
- Requires a period of time to develop
- Stimulates long-term "memory"
- Vaccines stimulate active immunity

b. Passive immunity

- Result of the transfer of antibodies from an immune source
- Immediate protection
- Short-term immunity with no "memory"
- Snake anti-venom, tetanus anti-toxin, and gamma globulin are passive agents.

Figure 1



Stimulates Active Immunity

Stimulates Passive Immunity

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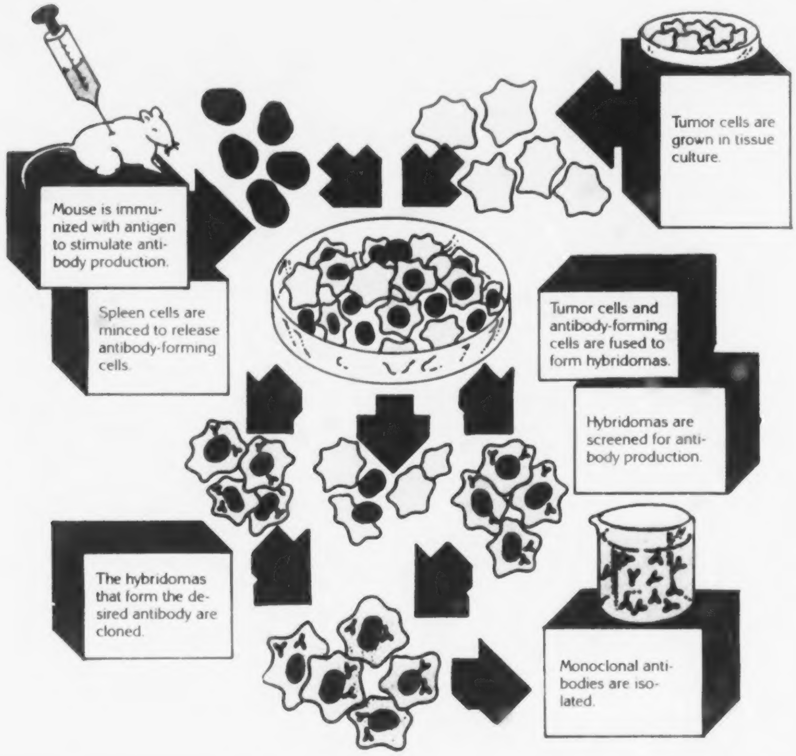
Information Sheet

8. Monoclonal antibody technology

a. Method of producing large numbers of pure antibodies with many useful functions.

Figure 2


Mouse is immunized with antigen to stimulate antibody production.
Tumor cells are grown in tissue culture.
Spleen cells are minced to release antibody-forming cells.
Tumor cells and antibody-forming cells are fused to form hybridomas.
Hybridomas are screened for antibody production.
The hybridomas that form the desired antibody are cloned.
Monoclonal antibodies are isolated.

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b. Replaces methods that resulted in small amounts of mixed antibodies (polyclonal antibodies).

c. Antibody-forming cells do not reproduce themselves continuously in culture, but some cancer-producing cells reproduce continuously in culture.

d. Fusion of an antibody-forming cell with a cancer-producing cell forms hybridomas that will create an immortal cell production line.

e. After culture, separation of antibodies from cancer-producing cells results in large quantities of pure antibodies called monoclonal antibodies (cloned from one antibody-forming cell).

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Information Sheet

9. Uses for monoclonal antibodies

- a. Control specific diseases
- b. Screen for early detection of disease or cancer
- c. Locate cancer cells within the body
- d. Carry anticancer drugs to cancer cells without affecting normal cells
- e. Isolate scarce proteins such as hormones or useful medical compounds
- f. Match tissue for organ transplant
- g. Detect early pregnancy
- h. Produce anti-serum (fluid portion of blood that contains antibodies) for pre-transfusion testing
- i. Test for presence of biologics and drugs
- j. Has potential for arthritis treatment
- k. Detect pathogenic organisms in food, water, or medical products
- l. Prenatal testing for genetic counseling

10. Technologies in animal biotechnology

- a. Artificial insemination
  - Involves several steps
    - — Collection of semen from quality sires, preservation, and storage by freezing in liquid nitrogen (-320° F)
    - — Transporting and holding semen in frozen state for long periods of time
    - — Delivery to female at proper stage of heat cycle
  - Allows combining of genetic traits for best possible combination of traits in the offspring
  - Allows a single high quality male to father many offspring

Information Sheet

- Over 50% of dairy cattle and about 10% of beef cattle in the United States are artificially inseminated.
- Use of this technology has more than doubled milk production since we began using it in the 1940s.

b. Embryo manipulation

- Hormone treatments induce development of many eggs (ova) in place of the one or few normally produced. This is called superovulation.
- Ova can be fertilized outside the body (in vitro) and prepared for transfer to another animal.
- Fertilized ova (embryos) can be implanted in another animal (surrogate) to grow until birth.
- Genetic makeup of the offspring is determined by the animal from which the ovum was derived and the male sperm used for fertilization.
- In early stages embryos can be split several times to produce several identical offspring (clones).
- Embryos can be sexed to determine the sex of the offspring.
- Preservation of fertilized embryos by freezing is being developed to allow transfer over long distances.

c. Hormonal technology

- Growth hormones produce profound effects on growth rate, productive capacity, and nature of the product produced.
- Hormones can be isolated from animals, produced by synthesis, produced by engineered organisms, or have levels produced elevated by genetic engineering of an animal.
- Chicken growth hormone can reduce broiler production time by 15%.
- Chicken molting hormone can increase egg production levels.
- Bovine somatotropin (Bst) is being produced by engineered organisms and is used to increase milk production in dairy cattle.
- Porcine somatotropin (Pst) is produced the same way and is used to increase the efficiency and quality of meat production in swine.
- Hormones are also used to regulate heat cycles—estrus synchronization.

Information Sheet

d. Antibiotic technology

- Production of penicillin from a fungus was the first application of this technology.
- Modified antibiotics from engineered organisms will be effective against more organisms and be less likely to become ineffective against resistant organisms.
- Cell fusion may result in gene expression for new and more effective antibiotics.

e. Direct genetic engineering technology

- Microinjection of DNA into early embryonic cells will change the genetic makeup of the newborn.
- Retroviruses, disease-causing viruses, can be altered to act as vectors for carrying useful DNA into animal cells.

11. Production applications of animal biotechnology

a. Introduction of economically significant traits by gene transfer

- More efficient utilization of feed
- Leaner meat
- Reaching market weights in a shorter period of time
- Disease resistance
- Increased reproductive capacity
- Increased adaptive ability

b. Reproductive management

- Artificial insemination
- Embryo transfer
- Sperm sexing
- Increase birth rate

Information Sheet

c. Hormone regulation

- Somatotropin regulation of growth and production
- Estrus synchronization for controlled birthing interval
- Growth promoting implants

d. Disease management

- Effective long-term vaccines
- Monoclonal antibodies for disease and cancer detection
- Monoclonal antibody drug carriers
- Interferon antiviral and anticancer agents

e. Feed enhancement

- Probiotic stress management
- Amino acid enhanced feeds
- Single-cell protein sources
- Liquid protein feed
- Engineered rumen bacteria for utilization of hard-to-digest feeds

Biotechnology in Animal Science
Unit 5

Assignment Sheet 1—Write Opinion Statements About Concerns in Animal Biotechnology

Name ______________________________ Overall Rating __________

Evaluation criteria	Rating
Opinion statement is clear	______
Opinion statement addresses one concern below	______
Opinion statement explains why student has that opinion	______

Introduction: The purpose of this assignment is to have students use critical thinking to form their own opinions about important issues facing agriculture and biotechnology.

Directions: Select one of the following questions about concerns in animal biotechnology and write a statement that presents your opinion. Also explain why you have that opinion. Be prepared to defend your opinion during class discussion or debate.

Concerns in Animal Biotechnology

1. Do we have the right to change the basic genetic makeup of animals?
2. If we change animals, do we have the right to change humans?
3. Should we try to increase animal production when we already have a surplus of many commodities?
4. What effect will more efficient production have on depressed markets?
5. Who will benefit from animal biotechnology—the large scale producer or the family farm?
6. Do we have the right to patent a living organism?
7. What will "exclusive rights" to specific animals cost producers?
8. What will the quality of life be for transgenic animals? Consider the burden of excessive production.
9. How will the competitive position of the United States in world markets be affected if we do not participate in animal engineering?
10. What effect will animal biotechnology have on the purebred industry?

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Biotechnology in Animal Science
Unit 5

Laboratory Sheet 1—Observe Antigen-Antibody Reactions

Name ______________________________ Overall Rating __________

Evaluation criteria	Rating
Opening entries made in laboratory notebook	_____
Solutions correctly prepared	_____
Test plates correctly prepared	_____
Analysis procedures followed	_____
Observations made and recorded	_____
Laboratory notebook entries completed	_____
Laboratory report completed	_____

Introduction: The purpose of this laboratory activity is to give students hands-on experience observing antigen-antibody reactions. This helps in a basic understanding of immunology.

Note: This experiment is based on a kit from Modern Biology, Inc., catalog number 2-8.

A. Materials (in addition to those in the kit)

50 ml graduated cylinder
500 ml beaker
Wide mouth pint jar for storage
4 — 30 ml test tubes
Test tube forceps
Gram scale or balance
Water bath for boiling water

B. Procedure: Follow the procedure in the kit instructions. Use the following completion checklist to check off each step as you complete it.

C. Completion checklist for antibody-antigen observation

1. Preparation of solutions

☐ a. Prepare gel buffer.

☐ b. Locate ready-for-use antiserum.

☐ c. Add ovalbumin to diluted buffer gel.

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Laboratory Sheet 1

2. Preparation of test plates

   - ☐ a. Prepare gel buffer and agarose.
   - ☐ b. Boil solution and prepare petri dishes.
   - ☐ c. Wait for media to solidify, at least 20 min.
   - ☐ d. Cut antibody wells in the gel.
   - ☐ e. Number the wells.

3. Analysis

   - ☐ a. Fill the central well with antibody solution.
   - ☐ b. Fill the outer wells with diluted ovalbumin from the prepared solution.
   - ☐ c. Cover and seal the petri dish lid with plastic tape or parafilm.
   - ☐ d. Record your name, date, and ovalbumin Ab-Ag on your petri dish base.
   - ☐ e. Keep the plate at room temperature and observe daily for precipitation lines. This may occur overnight or may take several days.
   - ☐ f. Maintain a record of this experiment in your laboratory notebook.
   - ☐ g. Write a laboratory report and turn it in for evaluation.

Biotechnology in Animal Science
Unit 5

Laboratory Sheet 2—Evaluate Semen

Name ______________________________ Overall Rating __________

Evaluation criteria	Rating
Opening entries made in laboratory notebook	
Equipment and materials set up and ready for use	
Mass motility observed and scored	
Individual motility observed and scored	
Average motility scored	
Morphology accurately scored	
Semen evaluation completed and scored	
Information legibly recorded in laboratory notebook	
Laboratory report completed	

Introduction: The purpose of this laboratory activity is to give student hands-on experience using a microscope to evaluate bull semen. They will score motility and morphology. These scores help producers decide if a bull is desirable for breeding.

A. Materials

Microscope with 10X, 40X, and 100X (oil immersion) objectives
Immersion oil for microscope
Several microscope slides and cover slips
Plate glass about 12″ by 12″
2 bricks
1 trouble light with 75 watt bulb
Fresh or frozen (or both) bull semen sample
20 ml normal saline solution (physiologic saline)
Semen stain (Hancock's or Blom's Eosin-Nigrosin Stain)
Water bath at 37° C (98° F)
2 eye droppers
Several test tubes
Glass thermometer for water bath

Laboratory Sheet 2

B. Procedure

☐ 1. Record opening entries in laboratory notebook.

☐ 2. Set up a water bath to maintain semen sample at 94° to 100° F (34° to 37° C).

- Method 1—Saucepan on a burner
- Method 2—Thermal container

☐ 3. Maintain a test tube of normal saline in the water bath. Maintain the semen sample in a test tube in the water bath.

☐ 4. Preheat microscope slides and cover slips by placing them on a clean glass plate supported on bricks with a 75 watt bulb underneath as a heat source. Leave slides on the glass plate for about 10 minutes before using them.

Note: Mass motility evaluation works well with fresh semen but not frozen since the latter is diluted.

☐ 5. Evaluate **mass motility** by placing a drop of fresh semen on a warmed microscope slide and quickly observing it under the microscope on the 10X objective. Focus on the semen and score mass motility using this scale:

Rapid swirling motion	Score 20
Slow swirling motion	Score 12
General motion but not swirling	Score 10
Very slow movement	Score 3
No movement	Score 0

Laboratory Sheet 2

☐ 6. Evaluate **individual motility** by placing a drop of fresh semen on a warmed slide and adding a drop of warmed saline solution. Mix the two together and cover with a warmed cover slip.

Note: Use thawed samples of frozen semen direct without saline dilution.

a. Focus and observe the sample at 40X.
b. Pick out an individual sperm cell and observe it move across the visual field. A strong sperm will move in a straight line across the field in less than 5 seconds.
c. Evaluate several cells and record an average score using this scale:

Rapid straight line movement across the field (5 sec. or less)	Score 20
Moderate straight line movement across the field (5 to 10 sec.)	Score 12
Slow straight line movement of slightly erratic motion	Score 10
Very slow erratic motion	Score 3
No motion	Score 0

☐ 7. Determine the **average motility** score. Total the mass motility and the average motility scores and divide by 2.

Note: If you did not do mass motility, use the individual motility score as the average score.

Mass motility score ____________________
Individual motility score ____________________
Total ____________________
Divide by 2 = Average motility ____________________

Record motility scores in your laboratory notebook.

☐ 8. Evaluate **sperm morphology** (structure). Place one drop of fresh semen on slide (does not need to be warmed); add one drop of saline and one drop of semen stain. Mix well and cover with a cover slip.

Note: Use the same procedure for a thawed sample of semen but do not add saline.

Slides can be stored for a few days after staining and covering. The rest of this laboratory sheet may be completed during another class period.

Laboratory Sheet 2

☐ 9. Place the slide on the microscope under oil immersion and 100X magnification. Search the slide and find areas where you see from 5 to 20 sperm cells in a visual field. Use the attached pictures at the end of the laboratory sheet to identify abnormal cells. Count the total number of cells in the field and then count the number of abnormal cells in each of the three groups. Record the information in your laboratory notebook using a chart similar to the one below:

field number	total cells	primary abnormalities	secondary and tertiary abnormalities
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
totals	100		

Note: Stop counting when you reach 100 total cells.

Laboratory Sheet 2

☐10. Evaluate **morphology** using the following scale:

Primary abnormalities	
less than 10	Score 40
10 to 19	Score 24
20 to 29	Score 10
more than 29	Score 3
Secondary and tertiary abnormalities	
less than 25	Score 40
26 to 39	Score 24
40 to 59	Score 10
more than 59	Score 3

☐11. Determine **average morphology** score. Add the primary score to the secondary and tertiary score and divide by two.

Primary abnormalities score ____________________

Secondary and tertiary abnormalities score ____________________

Total ____________________

Divide by 2 = Average score ____________________

Record this morphology score in your laboratory notebook.

☐12. Evaluate the semen sample by adding the average motility score to the average morphology score. Rate your sample using the following scale:

0 to 20	Unsatisfactory sample
21 to 40	Questionable sample
41 to 60	Satisfactory sample

☐13. Record all procedures, observations, and calculations in your laboratory notebook.

☐14. Write a laboratory report and turn it in for evaluation.

Laboratory Sheet 2

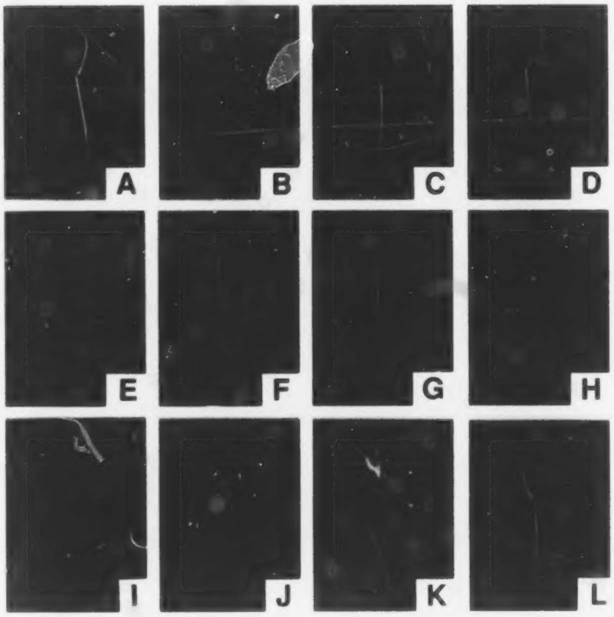

Figure 1. Primary abnormalities of bovine spermatozoa observed at 1000X magnification under differential interference contrast optics. (A) knobbed acrosome; (B) ruffled acrosome; (C) incomplete acrosome; (D) elongate ridge; (E) pyriform; (F) asymmetrical pyriform; (G) tapered; (H) pyriform; (I) cratered; (J) small head with abaxial implantation; (K) underdeveloped; (L) cratered

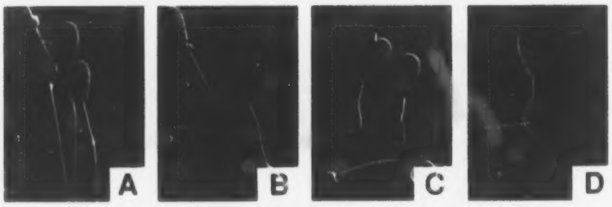

Figure 2. Secondary abnormalities of bovine spermatozoa observed at 1000X magnification under differential interference contrast optics. (A, B) each showing both proximal and distal protoplasmic droplets. (C) translocating protoplasmic droplets; (D) tail opening following droplet translocation.

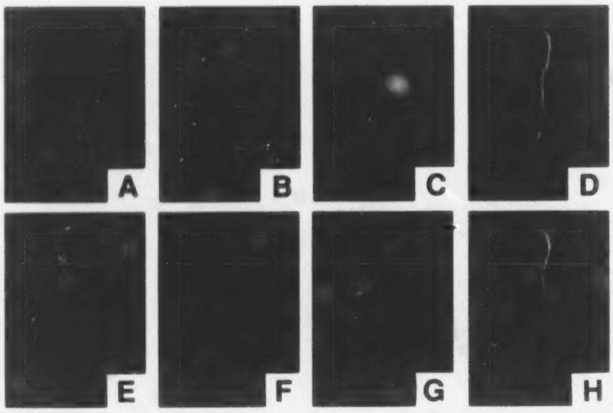

Figure 3. Tertiary abnormalities of bovine spermatozoa observed at 1000X magnification under differential interference contrast optics. (A) folded tail; (B) coiled double tail; (C) coiled tail; (D) coiled tail with droplet; (E) filamentous; (F) "corkscrew" midpiece with droplet; (G) "Dag" defect; (H) double tail.

Courtesy of Jere R. Mitchell, National Association of Animal Breeders, Columbia, MO

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Microbial Biotechnology in Agriculture
Unit 6

Objective Sheet

Unit Objective

After completing this unit, the student should be able to discuss the applications of microbial biotechnology in agriculture and be able to apply these in written and laboratory activities. The student will demonstrate these competencies by completing the assignment sheet, laboratory sheets, and written test with a minimum score of 85 percent.

Specific Objectives

After completing this unit, the student should be able to:

1. Match terms related to microbial biotechnology with the correct definitions.
2. Identify the types of microorganisms used in biotechnology.
3. List purposes of fermentation.
4. Match the components of a fermentation system with the correct descriptions.
5. Distinguish between the types of fermentation systems.
6. Arrange in order the steps in a fermentation process.
7. Match the products of fermentation with the correct descriptions.
8. Describe how microbial biotechnology can benefit production agriculture.
9. List the benefits of microbial biotechnology to the food processing industry.
10. List the benefits of microbial biotechnology to the environment.
11. Select true statements about the regulatory status of microbial biotechnology.
12. Identify foods produced by fermentation. (Assignment Sheet 1)
13. Observe the role of microorganisms in biodegradation. (Laboratory Sheet 1)
14. Demonstrate bacterial nitrogen fixation with inoculated clover seeds. (Laboratory Sheet 2)

Microbial Biotechnology in Agriculture
Unit 6

Suggested Activities

Instructional Plan

1. Read the unit carefully and plan for instruction. Study the specific objectives and develop your presentation.

2. Review teaching suggestions and plan classroom and laboratory activities.

3. Plan presentation to take advantage of student learning styles and to accommodate special-needs students.

4. Obtain videotapes, pamphlets, and other material to supplement instruction and stimulate student interest. See ordering information in the "Suggested Supplemental Resources" section.

5. Order and collect laboratory supplies needed to complete the laboratory activities.

   a. Laboratory Sheet 1 requires a compost bacterial starter culture. This can be obtained from garden centers or farm and home stores that sell composting systems.

   b. Laboratory kit #15-4720 (*Rhizobium* Inoculum with Clover Seeds) is recommended for Laboratory Sheet 2. The kit package is sufficient for 30 students. This can be ordered from:

      Carolina Biological Supply Company
      2700 York Road
      Burlington, NC 27215
      800-334-5551

   c. Both laboratory activities require several weeks to observe the results. Plan ahead and schedule the lab activities accordingly.

6. Review instructions for evaluating student performance, and make copies of unit evaluation forms.

7. Provide students with unit of instruction. Review objectives with them and inform them about materials included in the unit test.

8. Discuss assignment sheet and laboratory sheets. Review criteria for evaluation of these activities.

9. Discuss the use of the unit evaluation form with the students. Select and discuss the rating scale that will be used for student evaluation.

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Suggested Activities

10. Give the written test.

11. Compile assignment sheet ratings, laboratory sheet ratings, and written test scores on the unit evaluation form.

12. Reteach and retest as required.

Teaching Suggestions

Note: Skill areas appearing in bold face type in the teaching suggestions refer to the academic and workplace skills identified by the American Society for Training and Development (ASTD) and the U.S. Department of Labor and adapted by MAVCC.

1. Have students collect articles from the newspaper dealing with biotechnology and agricultural applications of biotechnology. Display articles on a bulletin board and talk about how they are related to the objectives of this unit.

2. Discuss with students that reading current reports, journal articles, and new publications on biotechnology is the primary way that all people stay up-to-date in biotechnology. Encouraging students to read and find new information on their own reinforces their **learning skills** and **foundation skills (reading)**.

3. Invite a representative from a local biotechnology company, college, research laboratory, or commodity group to talk to the class about agricultural biotechnology.

    a. Have the students prepare questions about applications of microorganisms in agricultural biotechnology.

    b. Have each student ask one question of the speaker.

    c. Preparing and asking questions helps to reinforce their **foundation skills (writing)** and **communication skills**.

4. Take students on a field trip to tour a biotechnology company, research laboratory, or other suitable facility. A waste water treatment plant is one example of microbial biotechnology that should be available for most schools to tour.

    a. You may want to videotape the tour to use with later classes, students who may have missed the trip, or for recruitment of students into your program.

    b. After returning to the classroom, ask students questions about the tour (oral discussion) or have them summarize the main points of the tour in writing.

Suggested Activities

c. The tour reinforces **group effectiveness skills** and the follow-up discusssion and review reinforces **foundation skills (writing)** and **communication skills**.

5. Have students report on examples of microbial biotechnology they have observed at home or on the farm. Have the students list any advantages they see in these products and processes. This activity reinforces their **foundation skills (writing)** and **communication skills (oral)**.

6. Participate in your local university's biotechnology programs for high school teachers and students. Workships and seminars associated with a university can improve student's **self-esteem** and **motivation** for learning more about biotechnology.

7. Have students research and report on job and educational opportunities in microbial biotechnology and discuss with them potential careers and the education necessary for these careers. Career exploration reinforces **personal management skills**, especially **goal setting** and **career development**.

8. Inform students about potential science fair projects in agricultural biotechnology. These projects encourage **creative thinking** and **problem solving** and help reinforce **foundation skills (science)**.

9. Have students write to local Congressional representatives to ask them their views on legislation regulating agricultural biotechnology. This activity can help increase their political awareness as well as reinforce their **foundation skills (writing)**.

10. Have students research and report on local and state regulations on the release of genetically engineered organisms to the environment. This reinforces their **learning skills** and **foundation skills** (**reading** and **writing**) and also increases their environmental awareness.

11. Have students research and write a report on the use of biotechnology in agriculture in Europe or Japan. This reinforces their **learning skills** and **foundation skills** (**reading** and **writing**). It can also make them more aware that biotechnology is used throughout the world, and the best ideas and applications increase a nation's international competitiveness.

12. Purchase other scientific kits to use as optional activities such as Carolina's Basic Fermentation BioKit, 20-2200; Novo Enzyme Kit, 20-2300; Cheese Production BioKit, 20-2305 or others that will aid in instruction of microbial aspects of biotechnology.

Suggested Activities

13. Have students bring in their favorite fermented foods (no alcoholic beverages) to share with the class for a Fermented Foods Party. Examples of fermented foods can be found in Student Supplement 1. Discuss the different types of organisms that are used to make each food and how they contribute to the characteristic flavor, texture, and aroma of the food. This helps improve students' **interpersonal skills** in a group setting and can reinforce **teamwork** if committees are used to plan and carry out the party.

14. Have students make yogurt to demonstrate the activity and function of bacterial cultures in fermented foods. Monitor the pH and physical appearance of the inoculated milk during incubation and compare it to an uninoculated milk sample. Observe the cultures present in the yogurt under the microscope. Active bacterial cultures can be obtained from commercial yogurt and used to inoculate whole milk (use 10 ml or about 3 tbs. per 8 oz. of milk) to make yogurt. This gives them hands-on laboratory experience and reinforces **foundation skills (science)**.

15. Have students add different items to the biocolumn made in Laboratory Sheet 1 to compare biodegradable and nondegradable materials. Plastic verses biodegradable plastic would be good to compare. Expanding the laboratory activity in this way helps students understand how scientists operate and how experiments evolve to solve new problems. This activity emphasizes **creative thinking** and **problem solving skills**.

16. Laboratory Sheets 1 and 2 are designed as group activities which reinforce **communication skills** and **group effectiveness skills**, especially **teamwork**.

Resources Used in Developing This Unit

1. Crueger, Wulf and Anneliese Crueger. *Biotechnology: A Textbook of Industrial Microbiology*. Madison, WI: Science Tech Inc., 1984.

2. Harlander, Susan K. and Theodore P. Labuza. *Biotechnology in Food Processing*. Park Ridge, NJ: Noyes Publications, 1986.

3. Walker, J. M. and E. B. Gingold. *Molecular Biology and Biotechnology*. London: The Royal Society of Chemistry, 1988.

4. Wu, Yeun C. (ed.). *Physiochemical and Biological Detoxification of Hazardous Wastes*. Lancaster, PA: Technomic Publishing Co., Inc., 1989.

Suggested Activities

Suggested Supplemental Resources

1. Audiotape—*Current Status and Future of Food Antimicrobials.* Available from:

   Sound Solution
   P.O. Box 566074
   Dallas, TX 75356
   214-258-6144

2. VHS videotape—*Art of Cheesemaking.* Available from:

   Wisconsin Milk Marketing Board
   4337 West Beltline Highway
   Madison, WI 53711
   608-271-1021

3. VHS videotape—*Connections: Animals, People, and Technology.* Introductory presentation on the importance of biotechnology to agriculture. Sponsored by the Industrial Biotechnology Association. Available from:

   Venard Films, Ltd.
   P.O. Box 1332
   Peoria, IL 61654
   309-699-3911

4. Booklet—*Biotechnology at Work.* Available from:

   Industrial Biotechnology Association
   1625 K Street, NW, Suite 1100
   Washington, DC 20006
   202-875-0244

5. *Bottle Biology Program* — Activity Sheets

   University of Wisconsin-Madison
   Department of Plant Pathology
   1630 Linden Drive
   Madison, WI 53706
   608-263-5645

Suggested Activities

Instructions For Evaluating Student Performance

Assignment Sheets — Be sure the student understands the criteria on which the evaluation is based. Assign a point value to each criterion and convert the total points to a percentage for grading.

Laboratory Sheets — Rate both process and product. The process should be based on the evaluation criteria for the laboratory activity. Observe the student during the laboratory activity and complete the rating by assigning a point value to each criterion and converting the point total to a percentage for grading. The laboratory product should be based on the completed laboratory report.

Performance evaluation can be based on the combined process and product evaluation. A suggested performance evaluation key is given below:

Performance level	Evaluation
90-100%	Skilled — Able to perform laboratory activity and arrive at a sound conclusion with no additional practice.
80-90%	Moderately Skilled — Able to perform most laboratory activities and arrive at reasonable conclusions.
70-80%	Limited Skill — Can perform some laboratory activities and work toward conclusions but needs additional practice in some areas.
0-70%	Unskilled — Not able to follow procedure and reach a satisfactory conclusion. Performance and evaluation must be repeated.

Microbial Biotechnology in Agriculture
Unit 6

Answers to Assignment Sheet 1

Question A.	Fermented food products for each of the commodity groups are listed in Student Supplement 1.
Question B.	1. The steps in the production of these foods will vary depending on the product. One key step common to the production of all fermented foods is the addition of a starter culture followed by some incubation time to allow for growth of the organisms. 2. The role that the microorganisms play in the production of these foods is to produce acid and other compounds that will act as natural preservatives as well as affect the texture, flavor, and aroma of the food.
Question C.	Biotechnology can be used to improve these products by altering the microorganisms used to make these products. Improving these cultures through biotechnology will result in more efficient means of food production, improved quality, and may lead to the development of new food products.

Microbial Biotechnology in Agriculture
Unit 6

Answers to Written Test

1. a. 2
   b. 4
   c. 10
   d. 6
   e. 11
   f. 1
   g. 8
   h. 9
   i. 5
   j. 3

2. a. Virus
   b. Bacteria
   c. Fungi

3. Any two of the following:

   a. Preserve food or feed products
   b. Improve the nutritional quality of foods or feed
   c. Enhance the flavor and texture of foods
   d. Produce cells, enzymes, metabolites, or modified compounds for industrial uses

4. a. 1
   b. 3
   c. 2

5. c

6. a. 2
   b. 1
   c. 5
   d. 3
   e. 4

7. a. 2
   b. 3
   c. 4
   d 1

8. a. Discussions will vary but should include at least one example of microbes being used to increase or improve crop production such as insecticides (*Bacillus thuringiensis*), frost prevention (*Pseudomonas*), or nitrogen fixation (*Rhizobium*). Students may give other examples. Accept those that show benefit to crop production.

Answers to Written Test

b. Discussions will vary but should include at least one example of microbes being used to increase or improve animal production such as disease prevention (*probiotics*) or recombinant products such as BST. Students may give other examples. Accept those that show benefit to animal production.

c. Discussions will vary but should include at least one example of microbes being used to increase or improve animal feed production such as silage or hay. Students may give other examples. Accept those that show benefit to animal feed production.

9. a. Improved production of fermented foods
   b. Development of new foods
   c. Improved food safety

10. a. Biodegradation
    b. Bioremediation

11. b, d, f

Microbial Biotechnology in Agriculture
Unit 6

Written Test

Name ______________________________ Score ______________

1. Match the terms on the right with the correct definitions

_____a. The vessel used in a fermentation process

_____b. The remaining waste liquid from a fermentation system

_____c. Microorganisms fed directly to animals to gain some benefit

_____d. A group of organisms that include yeasts and molds

_____e. Microbial cultures used in the production of fermented foods

_____f. Any substance that inhibits the growth of microorganisms

_____g. The sum of all the chemical reactions occurring within a living cell

_____h. Having to do with microorganisms

_____i. The process of converting some substrate to a product through the action of a microorganism

_____j. The chemical modification of organic compounds by living organisms

1. Antimicrobial
2. Bioreactor
3. Biotransformation
4. Effluent
5. Fermentation
6. Fungi
7. Inoculum
8. Metabolism
9. Microbial
10. Probiotics (direct-fed microbials)
11. Starter cultures
12. Substrate

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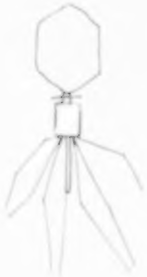
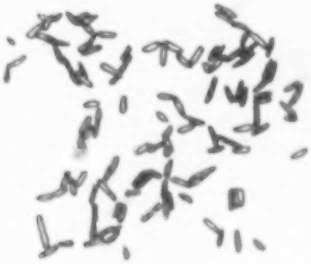
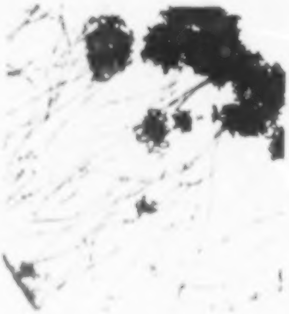
Written Test

2. Identify the types of microorganisms used in biotechnology that are shown below.







a. ____________ b. ____________ c. ____________

3. List two purposes of fermentation.

a. ______________________________________

b. ______________________________________

4. Match the components of a fermentation system on the right with the correct descriptions.

_____a. The equipment used for the growth of the microorganisms used in the fermentation process

_____b. The balanced mixture of required nutrients that allow growth of the microorganism in the bioreactor

_____c. The microorganism used in the fermentation process

1. Bioreactor
2. Culture
3. Medium

5. Distinguish between the types of fermentation systems by placing an "X" next to the definition of a batch fermentation system.

_____a. A fermentation system in which sterile nutrient solution is added in increments as the fermentation progresses

_____b. A fermentation system in which sterile nutrient solution is added to the bioreactor continuously at the same rate the fermented nutrient solution with microorganisms is removed from the bioreactor

_____c. A fermentation system in which no nutrients are added to the bioreactor during fermentation

Written Test

6. Arrange in order the steps in a fermentation process by numbering them from 1 through 5.

_____a. Add inoculum to the fermenter

_____b. Prepare the inoculum, and formulate and sterilize the medium

_____c. Process the effluent

_____d. Allow the culture to grow in the fermenter

_____e. Harvest the product from the fermenter

7. Match the products of fermentation of the right with the correct descriptions.

_____a.	The production of protein molecules which have specific catalytic functions	1. Metabolites
_____b.	The production of microbial cells	2. Enzymes
_____c.	The production of chemically changed organic compounds	3. Biomass
_____d.	The production of organic compounds which are produced by metabolizing cells	4. Modified compounds

8. Discuss how microbial biotechnology can benefit animal and crop production.

a. Crop production ____

____

____

____

b. Animal production ____

____

____

____

Written Test

c. Animal feed production ______________________________

____

____

____

9. List three applications of microbial biotechnology to the food processing industry.

a. ______________________________

b. ______________________________

c. ______________________________

10. List two applications of microbial biotechnology to improve the environment.

a. ______________________________

b. ______________________________

11. Select true statements about the regulatory status of microbial biotechnology by placing an "X" next to the true statements.

______a. The release of genetically engineered organisms is not controlled or regulate at this time.

______b. Products and processes are approved on a case-by-case basis.

______c. The International Food Biotechnology Council recently recommended that additional regulatory measures need to be established for biotechnology-derived foods.

______d. Congress is involved in regulating microbial biotechnology.

______e. The President of the United States makes all regulatory decisions about biotechnology.

______f. Existing regulations governing biotechnology are now being reviewed.

Microbial Biotechnology in Agriculture
Unit 6

Unit Evaluation Form

Student Name ________________________________ Unit Rating ____________

Assignment Sheet 1—Identify Foods Produced by Fermentation Rating ______

Comments: ____

____

Laboratory Sheet 1—Observe the Role of Microorganisms in Biodegradation Rating ______

Comments: ____

____

Laboratory Sheet 2—Demonstrate Bacterial Nitrogen Fixation with Inoculated Clover Seeds Rating ______

Comments: ____

____

Written Test Scores

Pretest ______ Posttest ______ Other ______

Other ____

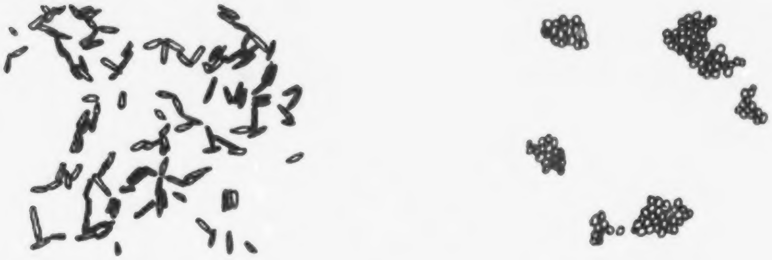
____

Teacher Signature ________________________________ Date ____________

Student Signature ________________________________ Date ____________

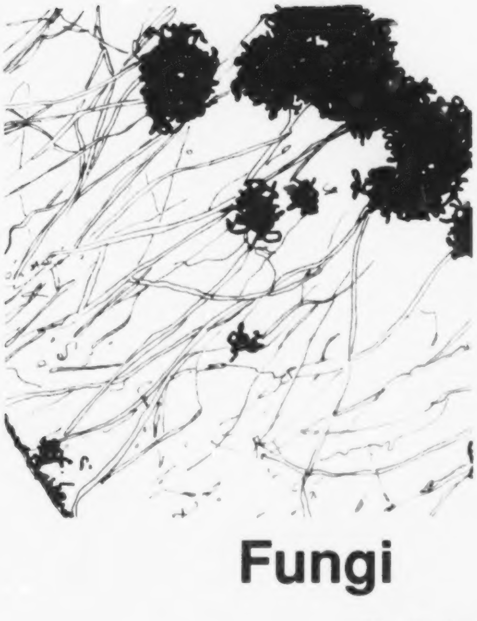
***Permission to duplicate this form is granted.**

Microorganisms Used in Biotechnology

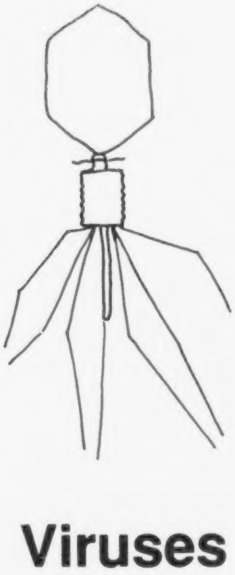


Rods Cocci

Bacteria



Fungi



Viruses

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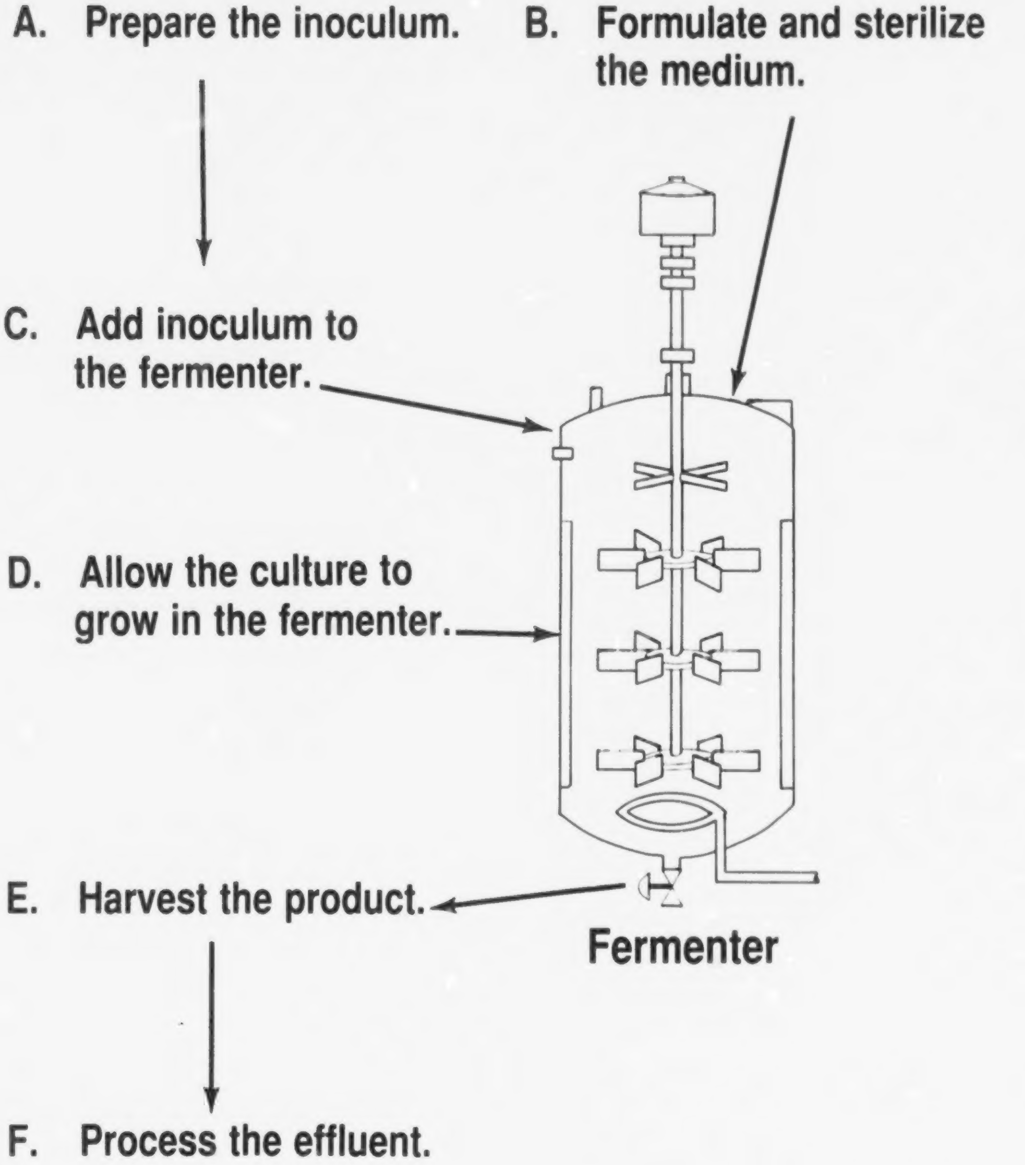
Steps in the Fermentation Process



A. Prepare the inoculum.

B. Formulate and sterilize the medium.

C. Add inoculum to the fermenter.

D. Allow the culture to grow in the fermenter.

E. Harvest the product.

F. Process the effluent.

Fermenter

Microbial Biotechnology in Agriculture
Unit 6

Information Sheet

1. **Terms and definitions**

   a. **Antimicrobial** — Any substance that inhibits the growth of microorganisms

   b. **Bioreactor (fermenter)** — The vessel used in a fermentation process

   c. **Biotransformation** — The chemical modification of organic compounds by living organisms

   d. **Effluent** — The remaining waste liquid from a fermentation system

   e. **Fermentation** — The process of converting some substrate to a product through the action of a microorganism

   f. **Fungi** — A group of organisms that include yeasts and molds

   g. **Inoculum** — The viable cells added to begin the fermentation

   h. **Metabolism** — The sum of all the chemical reactions occurring within a living cell

   i. **Microbial** — Having to do with microorganisms

   j. **Probiotics (direct-fed microbials)** — Microorganisms fed directly to animals to gain some benefit

   k. **Starter cultures** — Microbial cultures used in the production of fermented foods

   l. **Substrate** — The base material acted on by enzymes in the cells

2. **Types of microorganisms used in biotechnology**

   a. **Bacteria**—Unicellular organisms characterized by the absence of a formed nucleus

   Note: Bacteria are used in the fermentation industry to produce foods, vitamins, enzymes, organic acids, and a number of other compounds.

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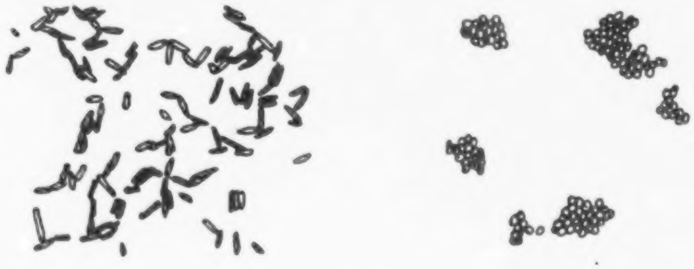
Information Sheet

Figure 1—Two of the common bacterial cell shapes:

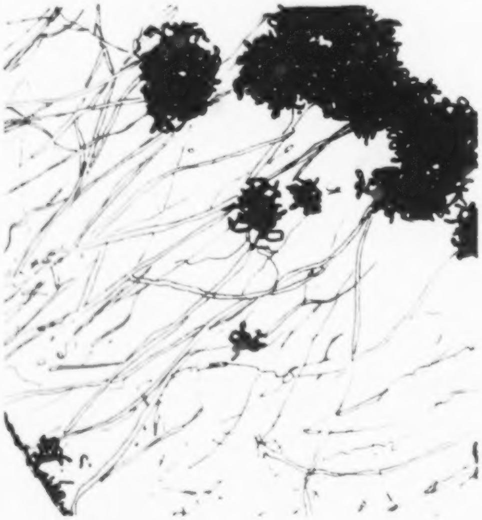


Rods Cocci

b. **Fungi**—A group of organisms with visibly evident nuclei that include yeasts and molds.

Note: These organisms are commonly used in the fermentation industry for the production of alcoholic beverages, antibiotics, pharmaceuticals, and a number of other products.

Figure 2—Mold culture



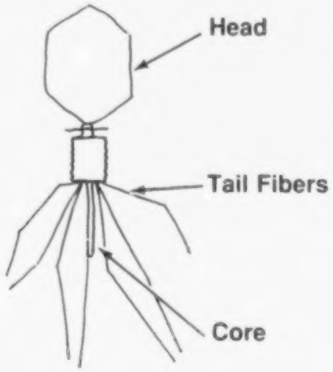
Note: Bacteria and fungi are also used as host cells for the production of recombinant DNA proteins such as animal and plant proteins.

Information Sheet

c. **Viruses**—Submicroscopic, noncellular particles composed of a core of nucleic acid and a protein coat; capable of reproduction only in a host cell

Note: Viruses are used to carry foreign pieces of DNA into host cells which is an important step in recombinant DNA technology.

Figure 3—Virus particle



3. **Purposes of fermentation**

a. **Preserve food or feed products** — The production of organic acids and other metabolites during fermentation will reduce the spoilage and pathogenic bacteria in feed or food products.

b. **Improve the nutritional quality of foods or feed** — Fermentation of feed or food products can increase the vitamin content, increase the digestability, and provide viable beneficial organisms.

c. **Enhance the flavor and texture of foods** — Fermentation of many foods gives the food desirable flavors, as well as improved texture.

d. **Produce cells, enzymes, metabolites, or modified compounds for industrial uses** — Industrial fermentations are used to produce many products that have numerous applications.

4. **Components of a fermentation system and their descriptions**

a. **Culture**—The microorganism used in the fermentation process. Different cultures such as yeast, molds, or bacteria can be used.

Examples: Yeast cultures are used in the production of alcohol and alcoholic beverages, mold cultures as commonly used to produce antibiotics, and bacterial cultures are used to produce organic acids, amino acids, and foods such as cheese and yogurt.

Information Sheet

b. **Medium**—The balanced mixture of required nutrients that will allow growth of the microorganism in the bioreactor

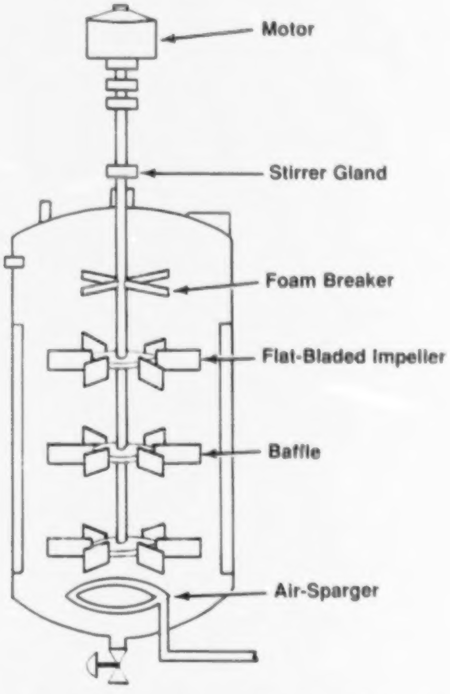
Note: The medium for fermentation contains a nitrogen source for protein production, a carbohydrate source for energy production, and any vitamins and minerals necessary for growth.

Example: Various products such as whey, soy meal, sugar beet molasses, and other by-products of industrial processes are often used as parts of fermentation media.

c. **Bioreactor** or **fermenter**—The equipment used for the growth of the microorganism used in the fermentation process

Figure 4—Bioreactor

Laboratory Size
(approximately 18" tall)



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Note: Industrial bioreactors may be up to two stories tall. They serve the same purpose as a laboratory bioreactor, just on a larger scale.

Information Sheet

5. Types of fermentation systems

a. **Batch fermentation system**—A fermentation system in which no nutrients are added to the bioreactor during fermentation

Note: A batch system is also referred to as a closed fermentation system. This type of fermentation system is common in many industrial fermentations.

Examples: Beer and cheese are made by batch fermentation processes. In beer and cheese fermentations wort and milk are the media and the fermentation is run until the substrate is converted into the product.

b. **Fed-batch system**—A fermentation system in which sterile nutrient solution is added in increments as the fermentation progresses

Note: A fed-batch system is used to prevent the inhibition of the product by components of the growth medium.

Example: Some vitamins and antibiotics are produced in a fed-batch fermentation systems where the final product may inhibit continued production of the desired product.

c. **Continuous fermentation system**—A fermentation system in which sterile nutrient solution is added to the bioreactor continuously at the same rate the fermented nutrient solution with microorganisms is removed from the bioreactor.

Note: A continuous system is also referred to as an open fermentation system. Although this is a very efficient method to produce products, this type of fermentation is not often used industrially due to problems of contamination and reduced product yields over time.

Example: High fructose corn syrup and some organic acids have been produced by continuous fermentation.

6. Steps in the fermentation process

a. Prepare the inoculum—The microorganism to be used in the fermentation process must be grown to provide enough actively growing cells for inoculating the bioreactor.

b. Formulate and sterilize the medium—All the necessary components for growth of the culture are combined and sterilized to remove any undesirable microorganisms.

Note: Steps a and b may be performed at the same time.

Information Sheet

c. Add inoculum to the fermenter.

d. Allow the culture to grow in the fermenter.

Note: Growth of the organism and production of the product is monitored throughout the fermentation. Other factors such as pH and temperature are closely controlled.

e. Harvest the product from the fermenter.

f. Process the effluent—The by-product materials from the fermentation are processed into secondary products.

Example: Yeast and brewer's mash are waste products of the fermentation process to produce beer. Both by-products are processed and sold commercially as secondary products for use in animal feed.

7. Products of fermentation

a. **Microbial biomass**—The production of microbial cells as the end product of fermentation

Example: The industrial production of baker's yeast, seed inoculants, and cheese starter cultures are examples of fermentations for the production of biomass. The cells are the desired end products.

b. **Metabolites**—The production of organic compounds which are produced by metabolizing cells

Examples:

Metabolite	*Commercial application*
Acetic acid (vinegar)	Used in the food industry
Acetone	Used as a solvent in the chemical industry
Lysine and other amino acids	Used as feed additives
Polysaccharides	Used as thickening agents in the food industry
Antibiotics	Used as therapeutic agents in medicine
Ethanol	Used for alcoholic beverages and fuel

Information Sheet

c. **Enzymes**—The production of protein molecules which have specific catalytic functions

Examples:

Enzyme	*Commercial application*
Rennin	Used to break down proteins in cheese production
Glucose isomerase	Used to convert glucose to fructose in the production of high fructose corn syrup
Amylases	Used in the baking, brewing, paper, and detergent industries to break down starch
Proteases	Used to break down proteins in the detergent, food, and film industries

Note: Microbial cells are commonly used for the commercial production of enzymes. Through genetic engineering, microbial cells have been designed to produce a number of animal and plant enzymes.

d. **Modified compounds**—The use of biotransformation which utilizes microorganisms to chemically modify organic compounds by fermentation

Example: The production of cortisone, a steroid hormone, from progesterone by microbial biotransformation has lowered the cost of cortisone from $200 per gram to less than $1 per gram.

Note: Many other biotransformations have been described; however, only a few have been used industrially. Utilization of genetic engineering techniques to isolate and improve specific enzymes involved in biotransformations will make these processes more cost-effective and expand their application.

Information Sheet

8. Applications of microbial biotechnology to benefit production agriculture

Note: Microbial cultures are being used to increase the efficiency and profitability of commercial animal and crop production. Application of recombinant DNA techniques to improve these cultures will extend their application in commercial agriculture.

a. Applications for crop production

- Microbial insecticides—Certain bacteria, viruses, and fungi have been identified which are toxic or pathogenic to insects and have application as biological insecticides.

  Example: *Bacillus thuringiensis*, a natural soil bacteria, is pathogenic to the larvae of *Lepidoptera* (butterflies and related insects). Ingestion of the protein toxin produced by *B. thuringiensis* induces a general paralysis in the larvae leading to death. Commercially, large scale cultures of *B. thuringiensis* are grown by fermentation, harvested after protein toxin production, and then dried and used as a dusting powder to control *Lepidoptera* insects.

- Preventing frost damage—Bacteria of the genus *Pseudomonas*, which are natural inhabitants of plants, have been isolated which will not act as nuclei for ice crystal formation, thus reducing losses due to frost damage.

- Nitrogen fixation—Bacteria of the genus *Rhizobium* are used as seed inoculants to fix nitrogen in leguminous plants reducing the need for nitrogen to be added to the soil.

  Note: An ultimate goal of genetic engineering is to introduce these desirable genes into plants and therefore improve production.

b. Applications for animal production

- Disease prevention—Viable microbial cultures are fed directly to animals to colonize their intestinal tract for the prevention of intestinal infections and to increase feed efficiency.

  Note: Microbial cultures which are fed to animals are also called probiotics. The use of these cultures offers a biological means to control the intestinal microflora that could reduce the need for subtherapeutic (growth-enhancing) levels of antibiotics in animal diets. Current regulatory laws do not allow companies with these products to make health claims without approving the product as a drug through FDA procedures.

Information Sheet

- Recombinant products—Microbial cultures have been engineered to produce a number of animal hormones used to increase milk and meat production.

  Example: Bovine somatotropin (BST) is a hormone produced by the pituitary gland of the cow that is essential for milk production. The gene for this hormone has been transferred to *E. coli* which has allowed for large scale production of this protein by fermentation. It is hoped that BST can be used to produce milk more efficiently and profitability.

c. **Applications for animal feed production**

- Silage—Bacterial fermentation of harvested forage crops preserves the nutritional value of the crops and ensures a year round supply of feed essential for livestock production.

  Note: Bacterial cultures such as *Lactobacillus* and *Pediococcus* are often used as inoculants for silage production. The addition of these lactic acid producing bacteria, which are normally found in plant material, increases the efficiency of the silage fermentation and prevents losses due to the growth of spoilage organisms.

- Hay—Naturally occurring bacteria can be added to high moisture hay to prevent losses due to the growth of spoilage organisms.

  Note: The role of bacterial cutures used as hay inoculants is not well understood but may involve the exclusion of spoilage organisms from hay.

9. Applications of microbial biotechnology in the food processing industry

a. **Improved production of fermented foods**—Recent advances in biotechnology will allow researchers to improve the microbial cultures used in food fermentations.

Example: In the cheese industry, bacterial starter cultures are susceptible to infection with bacterial viruses. The result of a viral attack on the starter culture is the loss of activities which are necessary for the production of cheese. Researchers have now identified genes that can help the bacteria resist viral infections. Bacterial starter cultures can now be constructed with increased resistance which will make these cultures more reliable in cheese production.

Information Sheet

b. **Development of new foods**—Microorganisms with new capabilities are being constructed through the use of genetic engineering. Ultimately, this will lead to the development of new food products utilizing these cultures.

Example: Yeast strains which have the ability to utilize more of the starch and sugar during the fermentation of beer without producing additional alcohol have been used for the production of lower calorie (light) beer.

c. **Improved food safety**—Biological control systems based on antimicrobial substances produced by bacterial cultures are being developed to control the growth of pathogens in the food supply.

Example: Many of the bacteria starter cultures used in cheese production produce potent antimicrobial compounds effective at inhibiting foodborne pathogens. Cultures of the antimicrobial compounds they produce will be incorporated into precooked food items to provide an additional barrier against foodborne pathogens and ensure product safety.

10. Applications of microbial biotechnology to benefit the environment

a. **Biodegradation**—The use of microorganisms to break down waste materials such as garbage and human excrement. This allows the nutrients in these materials to be returned to nature.

Examples: Sewage treatment, composting

b. **Bioremediation**—The use of biological agents, mainly microorganisms, to reclaim soils and waters polluted by substances hazardous to the environment and human health.

Examples: Microorganisms were used to remove oil from the shorelines of Prince William Sound, Alaska, following the Exxon oil spill.

11. Regulatory status of microbial biotechnology

a. **Current status**—Products and processes of microbial biotechnology are regulated differently dependent upon the industry and application.

- Products and processes are approved on a case-by-case basis.
- Testing and release of genetically engineered organisms is strictly controlled by the regulatory agencies established within the USDA.

Information Sheet

b. **Future trends**—Existing regulations are now being reviewed to determine if they are suitable for biotechnology products and processes.

- Bills that could make changes to current regulations for the release of genetically engineered microorganisms are being considered by Congress.
- The International Food Biotechnology Council recently recommended that no additional regulatory measures be established for biotechnology-derived foods.

Note: These recent changes point to a bright future for microbial biotechnology. Microbial biotechnology will be more widely and effectively applied when the regulatory, public, and scientific sectors share an understanding of the technology.

Microbial Biotechnology in Agriculture
Unit 6

Student Supplement 1—Summary of Fermented Food Products

Table 1
Microorganisms Used as Starter Cultures in Dairy Products

Product (Dairy)	Microorganisms Added
Cheese	
Parmesan, Romano	mixture of *Lactobacillus bulgaricus* and *Streptococcus thermophilus*
Cheddar, Colby	*S. lactis; S. cremoris*
Swiss, Emmenthaler	mixture of *L. bulgaricus* (or *L. lactis* or *L. helveticus*) and *S. thermophilus* and *Propionibacterium shermanni*
Provolone	mixture of heat-resistant *Lactobacillus* species and *S. thermophilus*
Blue, Gorgonzola, Roquefort, Stilton	*S. lactis*, *Leuconostoc* species, plus *Penicillium roqueforti*
Camembert	Lactic streptococci plus *Penicillium camemberti*
Brick, Limburger	mixture of *S. thermophilus* and *S. cremoris*: mixture of *S. thermophilus* and *L. bulgaricus*
Muenster	mixture of *S. thermophilus* and *Lactobacillus* species
Gouda, Edam	*S. lactis*
Mozzarella	mixture of heat-resistant *Lactobacillus* species and *S. thermophilus*
Cottage cheese, cream cheese	*S. lactis* or *S. cremoris*; mixture of *S. lactis* or *S. cremoris* and *S. diacetilactis* (or *Leuconostoc* species)
Fermented and nonfermented milks	
Bulgarian buttermilk	*L. bulgaricus*
Acidophilus milk	*L. acidophilus*
Buttermilk, sour cream	*S. lactis*; mixture of *S. cremoris* and *Leuconostoc citrovorum* (or *L. dextranicum*)
Yogurt	mixture of *L. bulgaricus* and *S. thermophilus*
Fresh milk	*S. diacetilactis*
Fresh milk	mixture of *S. diacetilactis* and *Leuconostoc cremoris*
Fresh milk	*L. acidophilus*
10% non-fat milk solids	*L. bulgaricus*
25% and 40% non-fat milk solids	*L. acidophilus*
Miscellaneous	
Butter	mixture of *S. diacetilactis* and *S. lactis*
Cream dressing for cottage cheese	*S. lactis; S. cremoris; S. diacetilactis*

Student Supplement 1

Table 2
Microorganisms Used as Starter Cultures in Vegetable and Fruit Products

Product (Vegetable or Fruit)	Microorganisms Added
Pickles	
Carrots	mixture of *Lactobacillus plantarum, L. brevis, Leuconostoc mesenteroides*, and *Pediococcus cerevisiae*
Cucumbers	mixture of *P. cerevisiae, L. plantarum*, and *L. brevis*; mixture of *P. cerevisiae* and *L. plantarum; L. plantarum*
Cucumbers-sliced	*L. plantarum*
Cucumbers-diced	*L. plantarum*
Mixed vegetables; green tomatoes, hot cherry peppers	mixture of *P. cerevisiae* and *L. plantarum; L. plantarum*
Various vegetables-diced	*L. plantarum*
Olives	*L. plantarum*
Sauerkraut (cabbage)	*L. plantarum*
Gari (cassava)	*L. plantarum*; mixture of *L. plantarum* and *Streptococcus* species; mixture of *L. plantarum* and *L. acidophilus*
Banana pulp	*L. bulgaricus; S. thermophilus; S. faecalis; L. fermentum; Leuconostoc mesenteroides*
Wines (various fruits; alcoholic fermentation	*Saccharomyces cerevisiae* var. *ellipsoideus; Saccharomyces* species
Wines (grape; deacidification)	*Leuconostoc gracile (L. oenos); Lactobacillus hilgardii; Schizosaccharomyces pombe*

Student Supplement 1

Table 3
Microorganisms Used as Starter Cultures in Plant Seed Products

Product	Cereal Grain	Microorganisms Added
Beer	Barley (malt); corn, rice, wheat barley, sorghum grain, soybean (malt adjunct)	*Saccharomyces carlsbergensis; S. cerevisiae*
Saké	Rice	*Aspergillus oryzae* followed by *S. saké*
Fermented soy milk	Water extract of soybeans	a number of *Lactobacillus* species; *S. thermophilus; Leuconostoc mesenteroides*
Natto	Soybeans	*Bacillus subtilis*
Tempeh	Soybeans; wheat; residue of soybeans after making soy milk of tofu; full-fat dehulled soybean grits wheat; oats; rye barley; rice; mixture of rice and soybeans; mixture of wheat and soybeans	*Rhizopus oligosporus; Neurospora* species
Miso (Bean paste)	Mixture of rice and soybean grits	*A. oryzae* followed by *S. rouxii*
Bread, doughnuts, pretzels, grape nuts, rolls	Wheat flour	*S. cerevisiae*
Sourdough, French bread	Wheat flour	mixture of *S. exiguus (Torulopsis holmii)* and *L. sanfrancisco*
Soda crackers	Wheat flour	mixture of *S. cerevisiae* and various *Lactobacillus* species

Student Supplement 1

Table 4
Microorganisms Used as Food Additives in Meat Products

Product (Meat)	Microorganisms Added
Semi-dry fermented sausages	
Lebanon bologna	mixture of *Pediococcus cerevisiae* and *Lactobacillus plantarum*
Summer sausage	*P. cerevisiae*; mixture of *P. cerevisiae* and *L. plantarum*
Cervelat	*P. cerevisiae*;mixture of *P. cerevisiae* and *L. plantarum*
Thuringer	*P. cerevisiae*
Teewurst	*Lactobacillus* species
Pork roll	*P. cerevisiae*
Dry fermented sausages	
Pepperoni	mixture of *P. cerevisiae* and *L. plantarum*
Dry sausage	*P. cerevisiae*
European dry sausage	*Micrococcus* species; mixture of *Micrococcus* species and *Lactobacillus*
Salami	mixture of *Micrococcus* species and *Lactobacillus* species; *L. plantarum*
Hard salami; Genoa	*Micrococcus* species; mixture of *Micrococcus* species and *P. cerevisiae*; mixture of *Micrococcus* species and *L. plantarum*
Mold ripened salami	*Penicillum* species; *P. janthinellum; P. simplicissimum; P. cyclopium; P. viridicatum*
Other fermented sausages	
Hot bar sausage	*P. cerevisiae*
Semi-dry turkey sausage	*P. cerevisiae*
Dry turkey sausage	*P. cerevisiae*; mixture of *P. cerevisiae* and *Lactobacillus plantarum*

Microbial Biotechnology in Agriculture
Unit 6

Assignment Sheet 1—Identify Foods Produced by Fermentation

Name ______________________________ Overall Rating __________

Evaluation criteria	**Rating**
Chart completed for question A-1	_____
Fermented foods consumed during a week are listed	_____
Steps in production process identified	_____
Role of microorganisms identified	_____
Ways for biotechnology to improve these products identified	_____

Introduction: Microorganisms are used in the production of many of the foods we eat on a daily basis. Fermentation has been used as a method for food preservation for centuries, yet many people are unaware of the important role microorganisms play in the production of fermented foods. The typical flavor, texture, and aroma of fermented foods is the result of the metabolic activity of the microorganisms. Today, research scientists are examining ways to improve these food products by improving the organisms that are used to make these products. Genetic engineering offers exciting opportunities to improve the organisms used in food fermentations. The dramatic impact these advances will have on the food industry will soon be realized.

Directions: Read Student Supplement 1. Identify one food product for each commodity that is produced by fermentation and answer the following questions.

A. Identify fermented foods and the microorganisms used to produce them.

1. Complete the following chart:

Commodity	**Name of the Food Product**	**Type of Microorganism Used**
Dairy		
Meat		
Cereal or Vegetable		

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Assignment Sheet 1

2. List the fermented food you consume in an average week.

B. Research the process used to make one of the fermented foods listed above and answer the following questions.

1. List the steps in the production process.

2. Identify the role the microorganisms play in the production of this food.

C. Describe how biotechnology can be used to improve these products.

Microbial Biotechnology in Agriculture
Unit 6

Laboratory Sheet 1—Observe the Role of Microorganisms in Biodegradation

Name ______________________ Overall Rating ________

Evaluation criteria	**Rating**
Procedure followed accurately	______
Results recorded in laboratory notebook	______
Lab report completed	______
Problem clearly defined	______
Hypothesis is recorded	______
Interpretation of results is reasonable	______
Conclusions are logical	______

Introduction: Microorganisms play an important role in the breakdown of waste materials in the environment. Biodegradation is the use of living things to breakdown waste materials. Composting is one example of the biodegradation of natural organic wastes that plays a vital role in recycling nutrients in the ecosystem.

During the process, microorganisms utilizing air and water decompose the material and release energy in the form of heat. In addition to composting, microorganisms can also be used to breakdown pollutants in the environment. The process of utilizing biological processes to reclaim polluted environments is known as bioremediation. Scientists in biotechnology are now studying the processes of microbial bioremediation and biodegradation. The focus of this research is to understand the mechanisms involved and to increase the efficiency and applications of these processes. Ultimately, the quality of the environment has a large effect on the quality and quantity of agricultural products produced. Therefore, as agriculturalists, we should all take an active role in these issues.

The purpose of this experiment is to determine the effect of microorganisms and air on the process of biodegradation. Composting is one example of the action of microbes in the biodegradation process.

Directions: Follow the procedures outlined below. Remember to record all results and observations in your laboratory notebook. Write and hand in your laboratory report when you have completed the experiment.

A. Write a hypothesis for this experiment.

B. Tools and materials

Thermometers, 4 (one needed for each column)
Bunsen burner

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Laboratory Sheet 1

Pyrex test tube
Scissors
Razor blade or knife
Electrical tape
Clear packing tape
Two-liter soda bottles, 12 total, (3 needed for each column), at least, 4 bottles with caps
Rubber bands, 4
Nylon stocking
Marking pen
Soil
Leaves and other plant material
Food scraps
Water
Compost bacteria starter culture—available at most farm and home supply stores

C. Procedure

Note: Work in groups of four.

☐ 1. Prepare four (4) biocolumns from the 12 two-liter soda bottles as follows:

  a. Remove the labels from three bottles.

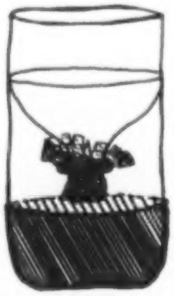
  b. Cut the bottoms off of two bottles just above the black plastic base.

  c. Cut the top off one bottle just above the shoulder of the bottle.

  d. Cover **one** bottle opening with a piece of nylon stocking and secure with a rubber band.

  e. Invert the top piece with nylon and place inside the base piece from step c.

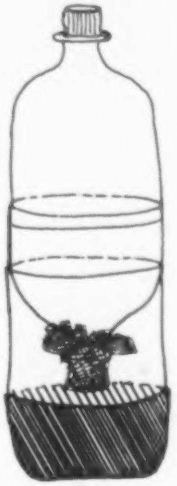
Figure 1



Laboratory Sheet 1

f. Slide the remaining top piece over the bottom of the inverted bottle by pushing in on the wall of the inverted bottle. Cap is needed on this top piece.

Figure 2



g. Repeat the procedure three more times to make four biocolumns.

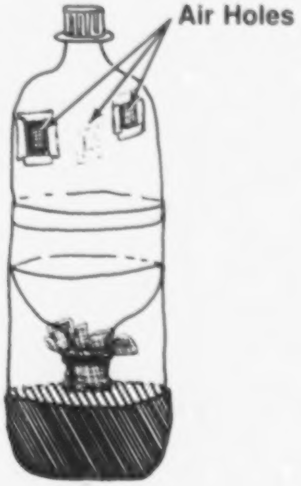
☐ 2. Make several air holes in only **two** of the columns using a sharp knife or by burning holes in the bottles using a heated Pyrex tube.

Caution: Be careful while punching the holes. Always point the knife away from you. Do not use your bare hands to hold the Pyrex tube while heating. Use oven mitts or hot pads.

Laboratory Sheet 1

☐ 3. Cover the holes in the bottles using a piece of nylon stocking and electrical tape.

Figure 3



☐ 4. Mix three parts waste material with one part soil and lightly moisten with water.

☐ 5. Divide the waste/soil mixture in half and add the bacterial starter culture to one-half of the mixture.

☐ 6. Add half the inoculated mixture to one of the biocolumns with a air holes and the other half to a biocolumn without air holes.

☐ 7. Add half the uninoculated mixture to a column with air holes and the remaining half to a column without air holes.

Note: The treatments being examined are:

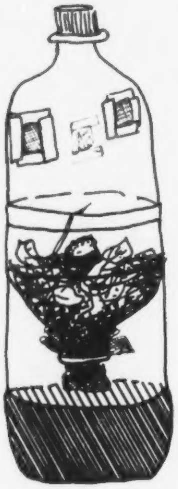
Bacterial culture
/ \
Added Not Added
/ \ / \
Air No Air Air No Air

Laboratory Sheet 1

☐ 8. Add a thermometer to each column so that the temperature can be read as the mixture decomposes.

☐ 9. Close the biocolumns and secure the sections with clear packing tape.

Figure 4



☐ 10. Label each column with your group's name or number, starting date, content, and treatment.

Figure 5

Group Name *Good Genes*

Starting Date *5/20/92*

Content *Leaves, grass clippings,*
orange peel, soil, twigs

Treatment *Air, No Culture*

☐ 11. Observe the columns daily for the first week.

☐ 12. Following the first week, observe the columns weekly for at least one month.

Laboratory Sheet 1

- ☐ 13. Record the temperature, odor, and evidence of decay for each column in your laboratory notebook.
- ☐ 14. Compile your results and write a laboratory report analyzing the data and drawing any important conclusions.
- ☐ 15. Turn in your laboratory notebook and report to your laboratory instructor for evaluation.

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Microbial Biotechnology in Agriculture
Unit 6

Laboratory Sheet 2—Demonstrate Bacterial Nitrogen Fixation with Inoculated Clover Seeds

Name ____________________ Overall Rating __________

Evaluation criteria	**Rating**
Procedure followed correctly	______
Results recorded in laboratory notebook	______
Lab report completed	______
Problem clearly defined	______
Hypothesis is recorded	______
Interpretation of results is reasonable	______
Conclusions are logical	______

Introduction: Microorganisms are found in a number of symbiotic associations with higher plants. One of the most well studied and agriculturally important associations is nitrogen fixation by bacteria isolated from root nodules of leguminous plants. In this symbiotic relationship, the bacteria benefit from the nutrients supplied from the plant while the plant benefits from the nitrogen fixed by the bacteria. Using molecular genetic techniques, scientists have identified the genes involved in nitrogen fixation. Eventually, this research will lead to biotechnology applications to improve the efficiency of nitrogen fixation in soil microorganisms and expand the application of nitrogen fixation to other plant crops.

The purpose of this experiment is to observe the effect of a bacterial inoculum used for nitrogen fixation on the growth of clover seeds.

Directions: Follow the steps outlined here and in the specific procedures included with your kit.

Note: Carolina Biological Supply Company Kit #15-4720 (*Rhizobium* inoculum with clover seeds) is recommended. Other seed inoculum kits for nitrogen fixation may be substituted.

☐ 1. Review the purpose of the experiment

☐ 2. Discuss a hypothesis for this experiment with your instructor and record it in your laboratory notebook.

☐ 3. Go over the materials provided in your kit and list those in your notebook.

☐ 4. Review the laboratory procedure with your instructor. Record any changes in the procedure in your notebook.

Laboratory Sheet 2

☐ 5. Perform the experiment as outlined in the procedure steps listed in the kit instructions.

☐ 6. Record all observations and results in your laboratory notebook.

☐ 7. Answer the summary questions included in your kit.

☐ 8. Compile your results and write a laboratory report for this activity.

☐ 9. Turn in your laboratory notebook and report to your instructor for evaluation.